THE 26TH JAIF ANNUAL CONFERENCE

第26回原産年次大会

APRIL 14～16, 1993

JAPAN ATOMIC INDUSTRIAL FORUM

日本原子力産業会議

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第２６回原産年次大会総括プログラム

平成５年４月１４日(水)〜１６日(金)
於　パシフィコ横浜 国際会議センター　１階メインホール

	第１日 ４月１４日(水)	第２日 ４月１５日(木)	第３日 ４月１６日(金)
午前	開会セッション (9:00〜13:15) 年次大会準備委員長挨拶 原産会長所信表明 原子力委員会委員長所感 ＜特別講演＞ ＜招待講演＞	セッション２ (9:00〜12:00) 「今なぜプルトニウムか」 〔パネル討論〕	セッション４ (9:00〜12:30) 「チェルノブイリ事故後７年を経た今は―何が真実か」 〔パネル討論〕
午後	(昼休み)	午餐会 (12:15〜14:15) 通商産業大臣所感 ＜特別講演＞ 於　パシフィコ横浜 3階 大会議室 原子力映画上映 (13:00〜14:00)	(昼休み)
	セッション１ (14:30〜18:15) 「わが国の原子力開発のあり方」 〔パネル討論〕	セッション３ (14:30〜18:00) 「原子力技術―その信頼性とは・・・」 〔パネル討論〕	セッション５ (14:00〜17:30) 「国際核不拡散のあり方―新たな情勢に対応して」 〔パネル討論〕
	レセプション (18:30〜20:00) 於　パシフィコ横浜 3階 大会議室		

第２６回原産年次大会
プログラム

基調テーマ「原子力―明日の地球のために」
平成５年４月１４日（水）～１６日（金）
於　パシフィコ横浜　国際会議センター１階メインホール
主催　（社）日本原子力産業会議

４月１４日（水）

＊本大会は全セッションを通じて日英同時通訳を行います。

開会セッション（９：００～１３：１５）

議長：谷　正雄　北陸電力(株)社長
大会準備委員長挨拶
唐津　一　年次大会準備委員長、東海大学教授

原産会長所信表明
向坊　隆　（社）日本原子力産業会議会長

原子力委員会委員長所感
中島　衛　原子力委員会委員長、国務大臣・科学技術庁長官

＜特別講演＞
「原子力を惑星の観点から考える」
Ｊ．Ｅ．ラブロック　英国学士院会員

議長：下邨昭三　日本原子力研究所理事長
＜招待講演＞
「原子力発電の安全および平和利用のための国際協力」
Ｈ．ブリックス　国際原子力機関（ＩＡＥＡ）事務局長
「米国における原子力―変革の課題」
Ｅ．Ｇ．ドプランク　米国原子力規制委員会（ＮＲＣ）委員
「ロシアにおける原子力発電―現状と将来展望」
Ｖ．Ｎ．ミハイロフ　ロシア原子力大臣

議長：野澤清志　日本原燃(株)社長
＜招待講演＞
「中国における原子力発電の現状と見通し」
蔣心雄　中国核工業総公司総経理
「フランスにおける原子力展望と燃料サイクル・バックエンド研究計画」
Ｙ．デスカタ　フランス原子力庁（ＣＥＡ）次官

４月１４日（水）

セッション１（１４：３０～１８：１５）

わが国の原子力開発のあり方

原子力委員会は現行の原子力開発利用長期計画（１９８７年６月策定）の見直しを行うことを決め、１９９２年９月からその具体的な作業を行っている。ここでは、わが国の原子力開発のあり方、すなわち原子力の位置づけ、研究開発、国際協力、燃料サイクル開発、とくに高レベル放射性廃棄物対策等の進め方などをテーマに、参加者との討論の場も提供しつつ、それらの討論を通して原子力開発利用長期計画への幅広い国民の意見の反映に努める。

議長：佐　和　隆　光　　京都大学教授・経済研究所所長

<問題提起>

「原子力開発における長期計画の諸問題」

秋　山　　守　　東京大学教授

<パネル討論>

パネリスト：

秋　山　　守	東京大学教授
藤　家　洋　一	東京工業大学教授・原子炉工学研究所長
Ｅ．Ｄ．フラー	米国原子力学会（ＡＮＳ）次期会長
Ｃ．ルビネ	欧州原子力学会（ＥＮＳ）会長
前　田　　肇	関西電力(株)取締役

コメンテーター：

Ｅ．Ｃ．ブローリン	米国エネルギー省原子力担当次官補代行
Ｉ．スブキ	インドネシア原子力庁次官

<参加者との討論>

注記：<参加者との討論>本大会では、内外の参加者とスピーカーの討論に十分時間を割いています。以下の各セッションとも来会のみなさんに活発な質問・コメントをお願いします。

レセプション（１８：３０～２０：００）

於　パシフィコ横浜　国際会議センター３階大会議室

4月15日（木）

セッション2（9：00～12：00）
今なぜプルトニウムか

わが国のプルトニウム利用開発計画が進展し、プルトニウムの取扱量や輸送量が増えつつある中で、その利用の是非をめぐる議論が内外で活発に展開されている。プルトニウム利用を行うか否かは、原子力が長期的なエネルギー安定供給に貢献できるかどうかを決める鍵となる重要な問題である。ここでは、他の物質やエネルギー源との比較等も行いながら、「プルトニウムとは何か」の議論に始まり、プルトニウムのもつリスク（潜在的危険性、軍事への転用可能性）やその管理方法、その経済性および情報提供のあり方等について言及し、プルトニウムに関連する課題の実態を明らかにする。

議長：鳥 井 弘 之　　日本経済新聞社論説委員

<基調講演>
「わが国のプルトニウム利用政策について」
石 田 寛 人　　科学技術庁原子力局長

<パネル討論>
パネリスト：
石 橋 忠 雄　　弁護士
加 納 時 男　　東京電力(株)取締役
菊 池 三 郎　　動力炉・核燃料開発事業団企画部長
瀬 川 至 朗　　毎日新聞社科学部

<参加者との討論>

４月１５日（木）

午餐会（１２：１５～１４：１５）
於　パシフィコ横浜　国際会議センター３階大会議室

通商産業大臣所感
森　　喜　朗　　　　　　　通商産業大臣

＜特別講演＞
「こころとことば」
江　藤　　淳　　　　　　　慶應義塾大学教授

原子力映画上映（１３：００～１４：００）
於　パシフィコ横浜　国際会議センター１階メインホール
・「地域と共に歩む　－　原子力発電所のある町から」
・「未来への架け橋　～Let's think together～　」

4月15日（木）

セッション3（14：30～18：00）
原子力技術―その信頼性とは・・・

技術の進歩には知識とノウハウが不可欠であるが、その進歩の過程とそこで得た経験、および技術開発にあたってのメリットなどについては、国民の間に必ずしもわかりやすく知らされていない。ここでは、国民に対し原子力に関連する情報を正しく提供し、原子力についての正しい認識の普及をはかるために、技術の中でも、より先進的な技術の一つである原子力技術をテーマにとり上げ、信頼性工学からみた原子力技術とは何か、また事故と故障をどのように捉えるべきかなど、事故と故障の概念をあらためて明らかにしながら、今日の原子力技術が抱える問題点をさぐり、その信頼性確保の考え方を討論する。

議長：勝部 領樹　　ジャーナリスト

＜問題提起＞
「原子力と信頼性」
唐津 一　　東海大学教授

＜パネル討論＞
パネリスト：

尾関 雅則	(財)鉄道総合技術研究所理事長
菅野 文友	東京理科大学教授
中村 政雄	読売新聞社論説委員
藤冨 正晴	通商産業省資源エネルギー庁 公益事業部原子力発電安全管理課長
松浦 祥次郎	日本原子力研究所理事

コメンテーター：
J．A．パーライト　　ウレンコ社社長

＜参加者との討論＞

４月１６日（金）

セッション４（９：００～１２：３０）

チェルノブイリ事故後７年を経た今は一何が真実か

チェルノブイリ事故から７年を経過した今日においても、同事故により放出された放射性物質の人体および環境等への影響については、今なお様々な情報が伝えられ、国際原子力機関（ＩＡＥＡ）の事故影響調査報告についても肝心の旧ソ連で説明することさえできない状態が続いている。その背景には、チェルノブイリ事故影響評価について全く内容の異なる情報が飛び交い、何が真実なのか、特定しきれない事情がある。ここでは、同事故の影響が深刻だといわれている実態を明らかにするとともに、混乱が発生する背景を確認し、今何が真実であり、今後、どのような対応を必要としているかを明確にする。

議長：田　島　英　三　　　(財)原子力安全研究協会理事長

＜基調講演＞

「チェルノブイリ事故後の影響評価」

藏　本　　淳　　　広島大学教授・原爆放射能医学研究所所長

＜パネル討論＞

パネリスト：

Ｅ．Ｐ．イワノフ	ベラルーシ保健省血液学輸血学研究所所長
小　出　五　郎	ＮＨＫ解説委員
藏　本　　淳	同　前
Ｇ．Ｋ．リーブス	英国立がん研究基金　疫学統計学者
Ａ．Ｆ．ツィブ	ロシア医学アカデミー会員・放射線科学センター所長

＜参加者との討論＞

4月16日（金）

セッション5（14：00～17：30）
国際核不拡散のあり方―新たな情勢に対応して

東西冷戦時代が終結し、核兵器等の取扱いの今後の位置づけがまだ不明確な世界情勢の中で、もはや2年後には、核不拡散条約（NPT）の延長可否の断をくだす時期を迎えることになる。原子力平和利用計画については、先進工業国はもちろん、今日、東アジアにおいても進展し、また世界的な核軍縮が促進され、核兵器解体からの核物質の抽出などに伴い、国際核不拡散のあり方が従来とは違った意味であらためて重要となってきている。ここでは、NPTの意義、役割等、1995年以降の同条約の延長を含めた国際核不拡散体制の維持、強化の方策を探る。

議長：堂之脇　光　朗　　　特命全権大使

＜基調講演＞
「国際核不拡散のあり方」
今　井　隆　吉　　　(社)日本原子力産業会議常任顧問
元軍縮会議日本政府代表部特命全権大使

＜パネル討論＞
パネリスト：

I．アッマド	パキスタン原子力委員会委員長
H．ブリックス	国際原子力機関（IAEA）事務局長
H．ドラフォルテル	フランス原子力庁（CEA）国際局長
今　井　隆　吉	同　前
B．サンダース	国際核拡散防止プログラム（PPNN）議長

＜参加者との討論＞

THE 26TH JAIF ANNUAL CONFERENCE
PROGRAM OVERVIEW

WED. APRIL 14	THU. APRIL 15	FRI. APRIL 16
Opening Session 9:00-13:15	Session 2 9:00-12:00 Why Plutonium Now?	Session 4 9:00-12:30 Seven Years After the Chernobyl Accident --What is the Real Truth?
	Luncheon 12:15-14:15 Large Meeting Room Conference Center, 3F Pacifico Yokohama	
	Film Show 13:00-14:00 Main Hall Conference Center, 1F Pacifico Yokohama	Session 5 14:00-17:30 Ways of International Nuclear Non-Proliferation --Meeting the New Situation
Session 1 14:30-18:15 Directions about Japan's Nuclear Future	Session 3 14:30-18:00 Nuclear Technology --from a Reliability Engineering Viewpoint	
JAIF Chairman's Reception 18:30-20:00 Large Meeting Room Conference Center, 3F Pacifico Yokohama		

Basic Theme

Nuclear Energy --- for the Earth's Future

WEDNESDAY, APRIL 14

OPENING SESSION 9:00 - 13:15

Chairman: Masao Tani
President
Hokuriku Electric Power Co.

Remarks by Chairman of Program Committee
Hajime Karatsu
Chairman
Program Committee
Professor
Tokai University

JAIF Chairman's Address
Takashi Mukaibo
Chairman
Japan Atomic Industrial Forum, Inc.

Remarks by Chairman of Atomic Energy Commission
Mamoru Nakajima
Minister of State for Science and Technology

Special Lecture:
"A Planetary View of Nuclear Power"
James E. Lovelock
Fellow of the Royal Society, UK

Chairman: Shozo Shimomura
President
Japan Atomic Energy Research Institute

Invited Lectures:
"International Co-operation for the Safe and Peaceful Use of Nuclear Power"
Hans Blix
Director General
International Atomic Energy Agency

"Nuclear in the United States: The Challenge of Change"
E. Gail de Planque
Commissioner
U.S. Nuclear Regulatory Commission

"Nuclear Power in Russia: Today and Tomorrow"
Viktor N. Mikhailov
Minister for Atomic Energy of the Russian Federation

Chairman: Kiyoshi Nozawa
President
Japan Nuclear Fuel Limited

"The Status and Prospects for Nuclear Power Development in China"
Jiang Xinxiong
President
China National Nuclear Corporation

"Prospects for Nuclear Energy in France and the Research Programme on the Back-End of the Fuel Cycle"
Yannick d'Escatha
Deputy Administrator General
Commissariat à l'Energie Atomique
France

SESSION 1 14:30 - 18:15
Directions about Japan's Nuclear Future

Chairman: Takamitsu Sawa
Professor
Director, Institute of Economic Research
Kyoto University

Keynote
"Issues on Long-Term Program for the Development and Utilization of Nuclear Energy"
Mamoru Akiyama
Professor
University of Tokyo

Panel Discussion
Panelists:
Mamoru Akiyama
Professor
University of Tokyo

Yoichi Fujii-e
Professor
Director, Research Laboratory for Nuclear Reactors
Tokyo Institute of Technology

Edward D. Fuller
President Elect
American Nuclear Society

Colette Lewiner
President
European Nuclear Society

Hajimu Maeda
Director
Kansai Electric Power Co., Inc.

Commentators:
Edison C. Brolin
Acting Assistant Secretary for Nuclear Energy
U. S. Department of Energy

Iyos Subki
Deputy Director General
National Atomic Energy Agency
Indonesia

Discussion with the Audience

Note: Discussion with the audience means discussion between speakers and the audience. The audience is invited to exchange their views and make comments during each discussion.

JAIF CHAIRMAN'S RECEPTION 18:30 - 20:00
LARGE MEETING ROOM, CONFERENCE CENTER, 3F, PACIFICO YOKOHAMA

THURSDAY, APRIL 15

SESSION 2 9:00 - 12:00
Why Plutonium Now?

Chairman: Hiroyuki Torii
Editorial Writer
Nihon Keizai Shimbun

Keynote
Hiroto Ishida
Director General
Atomic Energy Bureau
Science and Technology Agency

Panel Discussion
Panelists:
Tadao Ishibashi
Attorney at Law

Tokio Kanoh
Director
Tokyo Electric Power Co.

Saburo Kikuchi
Director
Policy Planning Division
Power Reactor and Nuclear Fuel Development Corp.

Shiro Segawa
Science Writer
The Mainichi Newspapers

Discussion with the Audience

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LUNCHEON 12:15 - 14:15
LARGE MEETING ROOM, CONFERENCE CENTER, 3F, PACIFICO YOKOHAMA

Remarks by Minister of International Trade and Industry
Yoshiro Mori
Minister of International Trade and Industry

Special Lecture
"Kokoro to Kotoba (Heart and Word)"
Jun Eto
Literary Critic
Professor
Keio University

FILM SHOW 13:00 - 14:00
MAIN HALL, CONFERENCE CENTER, 1F, PACIFICO YOKOHAMA

Latest films on Japan's nuclear research and development activities will be presented to those who are not attending the Luncheon. Films are in Japanese only.

SESSION 3 14:30 - 18:00
Nuclear Technology --- from a Reliability Engineering Viewpoint

Chairman: Ryoju Katsube
Journalist

Keynote
"Nuclear Technology and Reliability Engineering"
Hajime Karatsu
Professor
Tokai University

Panel Discussion
Panelists:
Masanori Ozeki
President
Railway Technical Research Institute

Ayatomo Kanno
Professor
Science University of Tokyo

Masao Nakamura
Editorial Writer
The Yomiuri Shimbun

Masaharu Fujitomi
Director
Nuclear Power Safety Administration Division
Agency of Natural Resources and Energy
Ministry of International Trade and Industry

Shojiro Matsuura
Executive Director
Japan Atomic Energy Research Institute

Commentator:
Mr. Jürgen A. Paleit
Managing Director
URENCO Limited

Discussion with the Audience

Note: Discussion with the audience means discussion between speakers and the audience. The audience is invited to exchange their views and make comments during each discussion.

FRIDAY, APRIL 16

SESSION 4 9:00 - 12:30
Seven Years After the Chernobyl Accident --- What is the Real Truth?

Chairman: Eizo Tajima
President
Nuclear Safety Research Association

Keynote
"Evaluation of Effects of the Chernobyl Accident"
Atsushi Kuramoto
Professor
Director, Research Institute for Nuclear Medicine and Biology
Hiroshima University

Panel Discussion
Panelists:

Eugene P. Ivanov
Director
Research Institute of Hematology and Transfusion
Ministry of Public Health
Belarus

Goro Koide
Commentator, Science and Technology
NHK (Japan Broadcasting Corp.)

Atsushi Kuramoto
Professor
Director
Research Institute for Nuclear Medicine and Biology
Hiroshima University

Gillian K. Reeves
Statistical Epidemiologist
Imperial Cancer Research Fund
Cancer Epidemiology Unit
UK

Anatoly F. Tsyb
Academician of Russian Academy of Medical Science
Director of Radiological Science Center

Discussion with the Audience
Note: Discussion with the audience means discussion between speakers and the audience. The audience is invited to exchange their views and make comments during each discussion.

SESSION 5 14:00 - 17:30
Ways of International Nuclear Non-Proliferation --- Meeting the New Situation

Chairman: Mitsuro Donowaki
Ambassador for Arms Control and Disarmament

Keynote
"Ways of International Nuclear Non-Proliferation"
Ryukichi Imai
Senior Counselor
Japan Atomic Industrial Forum. Inc.
Former Ambassador to the Conference on Disarmament in Geneva

Panel Discussion
Panelists:
Ishfaq Ahmad
Chairman
Pakistan Atomic Energy Commission

Hans Blix
Director General
International Atomic Energy Agency

Hubert de La Fortelle
Director
International Relations Division
Commissariat à l'Energie Atomique
France

Ryukichi Imai
Senior Counsellor
Japan Atomic Industrial Forum, Inc.
Former Ambassador to the Conference on Disarmament in Geneva

Benjamin Sanders
Executive Chairman
Programme for Promoting Nuclear Non-Proliferation

Discussion with the Audience
Note: Discussion with the audience means discussion between speakers and the audience. The audience is invited to exchange their views and make comments during each discussion.

大会準備委員長挨拶
年次大会準備委員長、東海大学教授
唐　津　一

原産会長所信表明
（社）日本原子力産業会議会長
向　坊　隆

原子力委員会委員長所感
原子力委員会委員長、国務大臣・科学技術庁長官
中　島　衛

＜特別講演＞
「原子力を惑星の観点から考える」
英国学士院会員
J．E．ラブロック

＜招待講演＞
「原子力発電の安全および平和利用のための国際協力」
国際原子力機関（IAEA）事務局長
H．ブリックス

「米国における原子力一変革の課題」
米国原子力規制委員会（NRC）委員
E．G．ドプランク

「ロシアにおける原子力発電一現状と将来展望」
ロシア原子力大臣
V．N．ミハイロフ

「中国における原子力発電の現状と見通し」
中国核工業総公司総経理
蔣　心　雄

「フランスにおける原子力展望と燃料サイクル・バックエンド研究計画」
フランス原子力庁（CEA）次官
Y．デスカタ

大会準備委員長挨拶

年次大会準備委員長
東海大学教授
唐津　一

ご臨席の皆様、第２６回原産年次大会の開催にあたり、大会準備委員会を代表してご挨拶を申し上げる機会を得ましたことは、私の深く慶びとするところであります。今大会に、日本国内のみならず、国際機関および世界各国から多くの権威者の方々のご参加を得て、本年次大会をここに開催する運びとなりましたことを、この上なく光栄に存じます。

ご高承のとおり、世界の一次エネルギー消費に占める発電部門の割合はすでに３割程度にのぼっておりますが、今日、この発電部門におけるエネルギー源として、原子力発電は大きな実績をしるしております。具体的にいえば、世界の発電量の６分の１を、またわが国の全発電量の約３割を原子力発電によって供給しております。

さて、東西冷戦時代が終結し、世界的な核軍縮が促進されるなど、最近の国際環境がめまぐるしく大きな変化を遂げている中で、わが国は、原子力分野はもとより広範囲にわたる種々の分野において積極的な国際貢献が要請されております。とりわけ、本年７月には東京サミット（主要先進国首脳会議）の開催が予定されるなど、政治・経済の両側面から、わが国の具体的かつ積極的な国際貢献策に大きな関心が寄せられております。

今大会では、このような諸情勢を踏まえつつ、その基調テーマを「原子力─明日の地球のために」と定め、地球および惑星の観点から原子力をとらえ、地球環境の保全と世界のエネルギー安全保障に大きく貢献する原子力の平和利用を進める上での国内的および国際的な今日の課題について、議論を行うことにしております。大会準備委員会での議論の結果、開会セッションを除く、すべてのセッションがパネル討論セッションになったのは、原子力をめぐる今日的課題が、それだけ重要な討論事項を抱え、かつ原子力への国民の理解促進が重要との証左といえましょう。

今大会のハイライトの一つである特別講演には、「地球が一つの生命体として機能、進化してきた」とのガイア仮説論を提唱し、世界から注目を集めたラブロック博士を英国か

ら招請し、また招待講演では、国際原子力機関をはじめ、米国、ロシア連邦、中国、そしてフランスの代表から、原子力発電をめぐる国際協力、あるいは各国の最新の原子力政策や原子力事情等についてのご見解を伺います。

「わが国の原子力開発のあり方」を論じることになっている大会初日の午後の国際パネル討論では、原子力委員会で行われているわが国の原子力開発利用長期計画の見直し作業を踏まえ、新長計策定をテーマに広範囲な意見を求めることにしております。よく長計の策定が「密室」の中で行われているとの陰口を聞きますが、本大会の公開の場で、国内からみた期待のみならず、海外からみたわが国の原子力政策への期待を、忌憚ない意見として出していただき、積極的な意見交換を期待したいと思います。

今大会の第二日目には、「今なぜプルトニウムか」をテーマにパネル討論を行います。フランスからわが国に返還されたプルトニウムの海上輸送など、マスコミを大いに賑わした、今、ホットな話題となっているプルトニウム問題に直接焦点を定め、プルトニウムを利用していく立場の代表、今のプルトニウム利用政策に厳しい意見をもつ立場の代表にパネリストとしてご参加いただき、そしてプルトニウム利用問題を現場で直接取材している新聞記者の目からみた生の声を、問題提起として出していただきます。今大会の中でも、よりホットな、そして活発な議論の展開がみられるものと考えております。

ところで、宇宙開発や電子機器、航空機産業等の分野では、信頼性工学が早くから発達し、機器の故障低減、稼働率の向上、安全性の確保が図られてきました。設備の安全性を追求する学問である信頼性工学は、私が専門とする分野ですが、今大会では、在来技術の分野において信頼性工学がもたらした経験と実績を披露しながら、原子力技術分野における信頼性確保の考え方等をテーマに、原子力技術開発の今後の課題を模索するパネル討論「原子力技術―その信頼性とは・・・」を行います。このパネル討論では、まず私から技術の信頼性と原子力との係わりなどについての問題提起の話をさせていただき、議論の展開を図ることにしておりますが、一般には誤解されがちな事故と故障の概念の違いについても、議論の対象にしたいと考えております。

この4月26日で旧ソ連のチェルノブイリ事故発生から7年となりますが、同事故の影

響評価については、今もって内容の異なる情報が飛び交い、何が真実なのか、特定しきれない状況が今なお存在しております。そこで、大会最終日には、「チェルノブイリ事故後7年を経た今は—何が真実か」をテーマに、このチェルノブイリ事故後の影響評価に関する国際パネル討論を行います。わが国の専門家のみならず、同事故を起こしたウクライナ、および同事故の影響が多大と伝えられるベラルーシからの放射線影響問題の専門家、それに英国からの疫学統計の専門家にもパネリストとしてご参加いただき、健康影響評価についての最新の状況が伺えるものと期待しております。

また大会の最後を締め括る討論テーマは「国際核不拡散のあり方—新たな情勢に対応して」であります。核不拡散条約（ＮＰＴ）が２年後の１９９５年に期限切れになるのを踏まえ、９５年以降の同条約の延長を含めた国際核不拡散体制の維持、強化の方策を探るのがこの国際パネル討論のねらいです。とりわけ、最近、北朝鮮がＮＰＴ脱退を宣言したこと、南アフリカが核爆弾を製造していた事実が判明したことなど、由々しき事態が醸し出されていますので、一躍、ここでの討論に大きな関心が寄せられ、その結果が注目されると思います。

以上、大会の準備委員長として、今大会のねらいにつきまして概略をご報告申し上げました。原産年次大会は３年前の京都大会（第２３回）以来、内外の参加者とスピーカーの討論にも十分な時間を割くことでプログラムを企画してきておりますので、時間の許す限り来会の皆様方にも討議に積極的にご参加いただければと思います。また大会の２日目と３日目、すなわち１５日と１６日の２日間については、一般公衆の方々を対象とした聴講者の方にもご参加いただけることになっておりますので、より活発な討論が交わされるものと期待しております。

最後に本年次大会における議長、スピーカーをご快諾いただきました大会関係者各位に厚くお礼を申し上げますとともに、本年次大会に参加された国内および海外からの皆様に感謝の意を表し、今大会が実りの多い大会として終わりますように心から念願をする次第でございます。どうもありがとうございました。

以　上

Remarks by Chairman of Program Committee

Hajime Karatsu,
Chairman,
Program Committee
Professor,
Tokai University

Ladies and Gentlemen!

It is a great pleasure for me to be able to extend greetings to you on behalf of the Program Committee at the beginning of the 26th JAIF annual conference. We feel it a great honor for us to be able to hold this year's conference with the attendance of representatives not only from Japan but also of international organizations and many authorities from the world.

As you may know well, electric power generation accounts for about 30% of the world consumption of primary energy. Today, nuclear power represents an impressive portion of electric power generation as an energy source. In concrete terms, nuclear power accounts for one-sixth of the world's electric power generated and for about 30% of Japan's electric power generation.

At a time when the world situation has undergone dramatic changes recently together with the termination of the Cold War and the consequent nuclear disarmament, Japan is required to make a positive international contribution not only in the area of nuclear power but also broadly in other areas. Particularly at a time when a Summit meeting is scheduled to be held in Tokyo in July this year, great attention is focused on Japan's concrete and positive measures for international contribution, political as well as economic.

In consideration of these developments in the world, we have decided to select "Nuclear Energy -- For the Earth's Future" as the basic theme of this conference so that this conference may concentrate its discussions on present-day domestic and international tasks for peaceful utilization of nuclear energy, which greatly contributes to the conservation of the global environment and energy security, viewing nuclear energy from the standpoint of the earth as a planet. As a result of discussions in the Program Committee, all the sessions excluding the opening session have been decided to be held as panel discussion sessions. This means that today's tasks regarding nuclear power are fraught with so many questions to be discussed and that it has become a matter of utmost importance to ensure public understanding on nuclear energy.

A highlight of this conference is a special lecture by Dr. James E. Lovelock, who has been invited to this conference. Dr. Lovelock is well-known for his Gaia hypothesis that the earth has functioned and evolved as a living body. Furthermore, our invited lecturers include representatives of the IAEA, and organizations related to nuclear energy in the United States, the Russian Federation, China and France. We expect them to speak about the question of international cooperation in nuclear power generation, as well as the nuclear energy policies of and conditions in their respective countries.

In the international panel in the afternoon on the first day of this conference, where "Directions of Japan's Nuclear Future" are to be discussed, opinions are invited to be expressed on a broad range of problems concerning formulation of a new long-term nuclear program, on the basis of the current Long-Term Program for the Development and Utilization of Nuclear Energy, which is now being reviewed by the Atomic Energy Commission of Japan. We hear people say that the long-term program is being formulated behind closed doors. Therefore in this occasion, we hope that not only Japanese representatives but also foreign participants will express their views frankly on and their expectations of Japan's nuclear policy and an active exchange of views will be held in this session.

On the second day of this conference, a panel discussion session is scheduled to be held on the theme "Why Plutonium Now?" The marine transportation of plutonium from France to Japan was reported noisily by mass media. This panel session will focus directly on the plutonium problem which is now a hot issue. The panelists include those who are for utilization of plutonium and others who take a critical attitude toward the policy of plutonium utilization, and also a science reporter who covered news on plutonium utilization on the spot and who will vividly describe actual scenes and present related problems. It is expected to be a session where discussions will be lively animated.

Now, reliability engineering has long been advanced in the areas of space science, electronic equipment, aviation and other industries and efforts have been made to reduce failures in equipment, improve its operation rates and its safety. Reliability engineering which is a science of assuring the safety of equipment, is the area of scientific research I myself specialize in. At this conference a panel discussion will be held to review the experience and achievements of reliability engineering in conventional technologies and to discuss the concept of reliability assurance in the field of nuclear technology and also to search for future tasks related to the development of nuclear technology under the theme "Nuclear Technology -- From a Reliability Engineering Viewpoint." In this panel session I will take the lead and present problems regarding the reliability of technology as related to nuclear energy to unfold discussions on this matter. I would like to see the discussions in the session focus on the difference of concepts between incidents and failures, which are liable to be misunderstood by the public.

It is seven years on April 26 this year since the Chernobyl accident. Even now there are different views regarding the evaluation of the effects of the accident, so that the situation is such that we are not certain about the truth. In view of this, on the last day of this conference, an international panel discussion is scheduled to be held concerning the evaluation of the effects of the Chernobyl accident under theme "Seven Years After the Chernobyl Accident -- What is the Real Truth?" Joining in the discussion as panelists will not only be Japanese scientists but also radiologists from the Ukraine where the accident occurred and from Belarus where the effect of the accident is reported to be serious, and also a cancer epidemiologist from Britain. We expect that we will be given the latest information on the effect of the accident on the health of people in the affected region.

The discussion theme also on the last day of this conference is "Ways of International Nuclear Non-Proliferation -- Meeting the New Situation." The purpose of this panel session is to search for ways of maintaining and strengthening the international non-proliferation regime, including the extension of the NPT after 1995, in view of the fact that the NPT is to be terminated in 1995, or in two years from now. Particularly in view of serious recent developments, namely, the fact that North Korea has declared that North Korea will pull out from the NPT and the astounding revelation that South Africa was manufacturing nuclear bombs, I think great attention will be paid to discussions and results of discussions in this session.

In the above, I have outlined as Chairman of the Program Committee the intent and purpose of this conference. Since the 23rd Kyoto conference held three years ago, the annual JAIF conferences have been planned so as to give sufficient time to Japanese and foreign speakers and also to participants and I hope as many participants in this conference will be given time as much as possible to participate in the discussions. Furthermore, ordinary public audience is welcome to participate in this conference on the second and third days, that is, on April 15 and 16, so that it is hoped that discussions will be more activated.

Lastly I would like to express my gratitude on behalf of the Program Committee to those who have willingly consented to our request to act as Chairman of this conference and speak as panelists, and also to those who have come to participate from various parts of our country and also from foreign countries. I sincerely wish this conference will be held successfully and fruitfully. Thank you very much.

第２６回原産年次大会会長所信表明

平成５年４月１４日

日本原子力産業会議

会長　向　坊　　隆

議長、御臨席の皆様、日本原子力産業会議会長の向坊でございます。第２６回原産年次大会の開会に当たり、主催者を代表して、一言所信を述べさせて頂きます。

わが国が、原子力開発に着手してから既に４０年近く経過しており、この間、ひたすら平和利用のみをめざし、原子力発電の積極的開発と、その長期的な裏付けとして、プルトニウム利用体系を中心とした核燃料サイクル確立に、一貫して努力してまいりました。その歩みは、決して早いものではありませんでしたが、わが国がウラン資源の全面利用を考えた最初の動機は、技術エネルギーである原子力が、石炭、石油に代表されるいわゆる化石燃料に比べて、供給の安定性から優れている、との判断に基づくものに他ならないのです。その意味でも、将来的にプルトニウム利用を進めてこそ、原子力利用の真の意味があるものと思います。被爆国日本が、率先して原子エネルギーを平和目的に利用できるよう、その技術を確立することは至極当然のことであり、我々の世界に対する責務であるとさえ考えます。

原子力技術は、もともと欧米において軍事目的として開発された技術を、平和目的に利用することから始められたわけですが、これをエネルギーとして民生に利用できるようにするには、並々ならぬ努力が必要でありました。幾多の改良・改善を経て、今日やっと軽水炉が名実ともに人類がコントロールできるようになったといえるでしょう。その結果、１９９２年には前年に続き、世界全体で２兆kWhを超える電力が原子力発電によって供給され、年間約４億９、０００万klの石油が節約されました。またわが国においては、１９９２年の総発電電力量の２９％にあたる２、１６０億kWhが原子力発電で賄われており、これによって１４％程度の輸入石油の節約に貢献しております。しかし

ながら、長期的にみた場合、原子力技術の基本は核燃料サイクルであり、使用済燃料を再処理し、そこから出てくるプルトニウムと減損ウランの利用を含めたサイクルを完結することによって、エネルギーの有効利用がはかられるばかりでなく、地球環境保全の優位性も期待されるのであります。

世界の人口増、経済発展により、エネルギー供給のバランスが大きく崩れ、破綻をきたす恐れのある２１世紀半ばまでに、われわれはエネルギーを安定に供給する方策をみいださなければなりません。そのためには、一方では石油、石炭などの資源を無公害で使う技術を確立するとともに、他方では省エネルギーを進め、エネルギーの利用効率を高めるなどの努力が必要であります。同時に人類の力で得たエネルギーである原子力を利用し、人類の発展のために安全で経済的なエネルギーとして安定に供給することが重要となります。ＦＢＲを中心とするリサイクルを完成することにより、資源的にも化石燃料の数百倍のエネルギーとして利用でき、原子力はこの役割を十分果たし得るものと考えます。

一方、化石燃料の消費量の増大はＳＯ2、ＮＯＸの排出量の増大につながり、最近では化石燃料の使用によるＣＯ2の増大が地球温暖化の要因として、深刻な問題となっております。ＣＯ2については多くの検討がなされておりますが、その一つのデータによりますと、石炭、石油、天然ガスのKWhあたりのＣＯ2排出量は、原子力のそれぞれ３４倍、２６倍、２３倍となっております。要するに原子力は、色々な面から大気汚染の防止に大きく貢献するものと期待されているわけであります。

わが国の原子力発電開発につきましては、軽水炉の実用化に多くの時間をかけてきました。今後とも、当分の間軽水炉が主流になると考えられておりますが、そのためには長寿命化対策や安全確保の一層の向上等、引き続き努力を行っていく必要があります。原子力発電の安全性、信頼性の向上への努力は、立地問題の解決につながるものであります。わが国のように国土が狭く、立地地点の少ないなかで電源を確保していく一つの方法は、既存の施設を最大限利用することであります。

さらに、軽水炉技術の高度化の一環として、新型軽水炉、すなわちＡＢＷＲ、ＡＰＷ

Ｒなどと呼ばれる原子炉が、日米協力のもとに開発され、１９９６年１２月には最初のＡＢＷＲとして、柏崎・刈羽６号機が運開する予定です。わが国では、長期的なエネルギー需給について検討した結果、西暦２０１０年に全電力の４０％程度を原子力で賄う計画が立てられております。

先にプルトニウムを有効利用してこそ原子力利用の意味があると申しましたが、わが国では、そのためにＡＴＲ、ＦＢＲ等の開発を進めるとともに、軽水炉でのプルトニウム利用の準備も進められております。これらについては、技術開発を進めることは勿論のこと、これを商業的に完全に使いこなすための努力をつづけなければなりません。

ＡＴＲ、ＦＢＲ等に利用するプルトニウムは、わが国では余剰を発生させないようバランスさせる計画であり、核物質管理上からも収支を明確にすることを基本方針としております。ＦＢＲは資源量を飛躍的に増大させるものとして技術開発が進められているものでありますが、将来は高レベル廃棄物の処分方法の一つとしても検討されており、人間の英知で、今当面している技術上の課題を克服し、将来エネルギー供給で重要な役割を果たすものと信じております。

再処理後の高レベル廃棄物については処分のための受け皿としての推進組織が近く発足する予定であります。この問題が原子力開発に不信感を抱かせている大きな要因にもなっていることから、官民力を併せて努力する必要があります。長期にわたる高レベル廃棄物の管理の確立如何が原子力開発の円滑な推進のためのカギを握っております。

米ロ２大超大国の核軍縮が進むなかで、１９９５年にひかえたＮＰＴ延長問題は、今後の原子力平和利用を進める上で重要な問題であります。ＮＰＴが核拡散防止に貢献したことは、多くの人々が認めるところでありますが、最近核兵器開発を目指すと疑われている国が散見されることから、核不拡散体制の一層の強化をはかる必要性が指摘されています。同時に、ＮＰＴそれ自体が従来から不平等条約として各国の不審を招いていることもあり、核保有国がどのようなシナリオで核をなくすかを明かにすることが重要であります。

以上述べましたような、原子力開発を、一層進めるためには大きな問題が数多く残っ

ています。

わが国はこれまで原子力先進国より技術を学び、優先的に研究開発費を投入し、それを日本独自の技術としてまいりました。しかし、今後は、日本も世界の原子力のために積極的に寄与すべきであると思います。そのような問題としては基礎研究をはじめとする研究開発、ＦＢＲ，高レベル廃棄物の処理処分、核融合等多くの課題があります。特にＦＢＲを実用化するにあたっては、この秋に運転を開始する予定の「もんじゅ」を安全確実に運転することが第一であり、このプロジェクトを、あるいは国際的な共同開発プロジェクトに供するのも一案かと考えます。

また、原子力分野への優秀な技術者、研究者を確保するためには、大学における基礎研究の充実や研究炉等基礎研究施設の確保が重要であります。そのために、例えば”原子力の国際研究センター”のようなものをつくって活性化をはかる必要もありましよう。

以上、わが国の原子力開発に関して私見をまじえて申し述べましたが、今回の年次大会では、世界の原子力開発の考え方、日本の原子力開発計画、原子力技術の信頼性、核不拡散等ホットな問題を取り上げ広く議論していただくためのプログラムを用意いたしました。皆様からの忌たんのないご意見を賜りたいと存じます。

最後になりましたが、年次大会の準備委員長、及び準備委員、各セッションの議長のかたがた、この大会のためにご参集いただきました海外、国内の発表者の方々、並びに会場の皆様に、心よりお礼を申し上げ、私の所信とさせていただきます。

ご静聴、ありがとうございました。

以上

The 26th JAIF Annual Conference

Address

Takashi Mukaibo
Chairman
Japan Atomic Industrial Forum, Inc.
April 14, 1993

Chairman, distinguished guests and participants, I am Takashi Mukaibo, Chairman of the Japan Atomic Industrial Forum. I have the pleasure of opening the 26th JAIF Annual Conference with an address on behalf of the sponsoring organization.

Nearly 40 years have passed since we started the development of nuclear energy in Japan. The peaceful use of nuclear energy is the only purpose we have pursued all this while. We have consistently used our efforts to promote the development of nuclear power, following it up from a long-range point of view with the closing of a nuclear fuel cycle based on the recycling of plutonium. We have not exactly made fast progress. But the primary motivation for the idea of making full use of uranium resources in Japan is the understanding that nuclear power, a technology-intensive source of energy, assures greater stability of supply than may be expected from coal, oil and any other fossil fuel. That is why I believe that the utilization of nuclear energy can only have real significance if use is found for plutonium in the years ahead. It is only natural that a technology should be established in Japan which will enable the people of the victim country of atomic bombing to take the initiative in promoting the peaceful use of nuclear energy. I would say that is also the way the Japanese should discharge their responsibility to the world.

Nuclear technologies were first started with the harnessing for peaceful purpose of technologies originally developed for military purposes in the United States and European countries. Great efforts have had to be made to put them to use in the commercial field of energy supply. Many alterations and improvements have been needed to make light water reactors fully available today under the control of mankind. As a result, the whole world was supplied through nuclear power with more than 2,000 billion Kwh of electricity in 1992, as it was in the previous year. This represented an annual saving of some 490 million kiloliters of oil. In Japan, nuclear power plants produced 216 billion Kwh of electricity in 1992, contributing to 29 percent of the nation's total generated electricity that year. This achieved a saving of some 14 percent on imported oil. However, when viewed in the long term, the underlying principle of nuclear technology is in the closing of a nuclear fuel cycle. Spent fuel should be reprocessed to recover plutonium and depleted uranium for use in cycles, so that efficient use can be found for nuclear energy, eventually to let it show its advantages in protecting the global environment.

By the time when the population increase and economic development of the world are likely to disturb the balance of energy supply to the point of disruption in the middle of the 21st century, we must find out measures for an uninterrupted supply of energy. To achieve this goal, efforts are needed to establish technologies which will make the use of oil, coal and other resources free of pollution, on one hand, and which will promote energy conservation and raise the efficiency of energy use, on the other. It is also important that nuclear power, an energy source that has come through the agency of mankind, assures constant supply of the safe and economic energy needed for the survival of mankind. The FBR and all other requirements for recycling must be provided to make nuclear energy hundreds of times as useful as can be expected from any fossil fuel. I believe in the capability of nuclear power to play this role.

Meanwhile, increasing consumption of fossil fuel is adding to the spread of SO_2 and NO_X emissions. The use of fossil fuel in recent years has caused the increase of CO_2 to make global warming a serious problem. Many studies have been made on CO_2. They have produced data showing that coal, oil and natural gas are responsible for CO_2 emissions to the extent of 34 times, 26 times and 23 times respectively over the per-Kwh level of nuclear power. In other words, nuclear power is expected to go a long way toward preventing air pollution.

The Japanese interests involved in the development of nuclear power have spent a lot of time trying to commercialize light water reactors. The LWRs are likely to retain their dominance for some more time in the future. So the necessity exists to organize measures for an extended service life, greater safety and all the other features necessary to keep them in existence. Striving to improve the safety and reliability of nuclear power will eventually lead to a solution for the problem of nuclear siting. One way to assure power supply for a small country short of additional building sites, like Japan, is to make full use of existing facilities.

As a step toward the further improvement of LWR technology, Japan and the United States have been cooperating in the development of advanced light water reactors, such as the so-called ABWR and APWR. The first ABWR to come off is scheduled for inauguration as Kashiwazaki Kariwa Unit 6 in December, 1996. Studies of a long-range supply and demand situation for energy in Japan have led it to project the proportion of nuclear power as some 40 percent of all electricity to be generated for the year 2010.

I said earlier that the utilization of nuclear energy can only have significance if efficient use is found for plutonium. That is why Japan is preparing, while promoting the development of ATRs and FBRs, to use plutonium in light water reactors. For present purposes, we are under the necessity of developing such technology, plus the expertise necessary for us to put it to commercial use.

The stock of plutonium for use in ATRs and FBRs will be kept in equilibrium under plans to let there be no surplus in Japan.

The basic policy is to bring it into clear balance for the purposes of nuclear material control. The FBR is a technological development designed to have its resources in increasing quantities. It is also considered as a method for the disposal of high level radioactive waste in the future. I believe in the human wisdom that the way will eventually be cleared for technology to play an important role in the future supply of energy.

An organization is to be set up soon which will make preparations for the disposal of high level radioactive waste from reprocessing plant. All interests involved, government and industry alike, are advised to face up to the implications of this issue, as it is providing a major factor for public distrust with the development of nuclear power. Establishing long-range control over the disposal of high level radioactive waste is the key to facilitating the promotion of nuclear power development.

Amid U.S. and Russian moves as two military superpowers toward nuclear disarmament, the Nuclear Non-Proliferation Treaty is scheduled for review in 1995 as an important step toward peaceful use of nuclear energy in the years ahead. Many people give the NPT credit for its long-standing contribution to the prevention of nuclear proliferation. But since some countries are suspected of moving toward developing nuclear weapons in recent years, the need is arising to reinforce the nuclear non-proliferation regime. In view of the fact that the NPT itself has been open to doubt with many countries finding it to be an unequal treaty, it is also important that nuclear-weapons states show what scenarios they have under which to get rid of their nuclear armaments.

Many big problems remain to be solved before we can push ahead with all the plans that I have stated above for the development of nuclear energy.

We have so far acquired technologies from advanced nuclear-energy countries and followed them up with research and development under a priority funding policy, until they have been assimilated with indigenous Japanese technologies. From now on, however, Japan is advised to contribute actively to the world nuclear community. In this respect, problems remain over the conduct of research and development, including fundamental research, as well as the development of FBRs, the management and disposal of high level waste, and the study of nuclear fusion. the first step toward FBR commercialization, in particular, is to ensure the secure and reliable start-up of the prototype reactor, "Monju" as scheduled for the fall of this year. I might suggest that this project could be put to work overseas as a proposition for international joint development.

If the nuclear community is to be recruited with competent engineers and researchers, it is important to build up university education in fundamental research and provide research reactors and other facilities for fundamental research. It might be advisable, for example, to set up something like an "international nuclear research center" as a means of revitalization.

So far, I have gone over the development of nuclear energy in Japan as it is, and as I personally see it. Now this Annual Conference offers a program for debate on world ideas and Japanese plans for the development of nuclear energy, as well as the reliability of nuclear technology, the prevention of nuclear proliferation and all other controversial issues. You are invited to offer your unreserved opinions.

I wish to close my address by expressing my heartfelt gratitude to the chairman and members of the Organizing Committee for the Annual Conference, the chairman of all conference sessions, the speakers coming to the conference from overseas and from within Japan, and all those present in the conference hall.

Thank you very much.

第２６回原産年次大会

大山原子力委員会委員長代理　所感

（はじめに）

議長ならびに会場の皆様、

本日、第２６回原産年次大会が、内外多数の方々の出席のもと、盛大に開催されますことは誠に喜ばしく存じます。

向坊会長、唐津大会準備委員長を始め、大会の開催に御尽力された皆様方に心からお祝いを申し上げますとともに、原子力分野で指導的な役割を果たされている皆様と、この場に会することができ、大変喜ばしく思います。

本日は、日本の原子力平和利用とその立場について述べるとともに、現在原子力委員会において審議を行っている新たな原子力開発利用長期計画の策定について申し述べたいと思います。

（日本の原子力平和利用とその立場）

日本は、天然資源が乏しく、特にエネルギー資源においては、外国依存度が先進国中最も高い国です。化石燃料の輸入を抑制するため、科学技術に基づくエネルギー源である原子力発電を推進することが重要と考え、１９６５年には最初の原子力発電所を運転開始させ、それ以来原子力発電容量を着実に増加させてきました。現在、日本においては発電用

原子炉４３基が運転中であり、その容量は約３４．６ＧＷで、１９９１年度実績で、一次エネルギー供給の約９．８％、総発電電力量の２７．１％を賄い、主力電源として着実に定着してきています。

現在の軽水炉による発電は、今後さらに増加させねばなりません。これは、化石燃料資源の保護に資するばかりでなく、炭酸ガス排出抑制の目標を達成するためにも必要です。しかし、そのためには発電所の安全運転実績を積み重ねることが最も大切であると考えております。

原子力は、少量の資源から技術によって大量のエネルギーを生み出すという他のエネルギーにない特長を有しています。また、原子力発電は、核燃料リサイクルの確立によって資源の格段の有効利用が図られます。

日本はウラン資源も持たないので、原子力の開発利用に着手した段階から、使用済核燃料を再処理し、回収されたプルトニウム及びウランをリサイクルし、核燃料として利用することを目指す核燃料リサイクル政策を採用し、技術開発を行ってきました。

核燃料のリサイクルに必要な技術は、研究開発においても、施設の整備においても、長い期間の継続的な努力が必要です。再処理については、東海村の小規模な工場（ｐｌａｎｔ）で十数年経験を積み、現在、六ケ所村の工場建設が始まろうとしています。高速炉については、原型炉「もんじゅ」が今秋臨界となる予定です。次には、その成果を踏まえて実証炉の建設、運転を行い、２０２０年ないし２０３０年における高速炉の実用化につなげることにしています。このＦＢＲ原型炉「もんじゅ」の燃料製造に必要なプルトニウム燃料のフランスからの返還輸送が昨年

から本年にかけて実施されました。航路に近い国の方々にご心配をおかけしましたが、おかげさまで予定通りトラブルなく終了いたしました。

また、現在および近い将来における原子力発電計画の主流である軽水炉において、段階的、計画的にプルトニウム利用を進め、エネルギー供給面で一定の役割を果たすとともに、将来の高速炉の実用化時代に向けて、実用規模の核燃料のリサイクル体系の整備を進める計画です。

日本は、原子力基本法に基づき、厳に平和目的に限って、原子力開発利用を進めてきましたが、今後、核燃料のリサイクルを推進していく上で、核兵器不拡散に対し、引き続き厳格に取り組んでいく決意です。即ち、我が国の核燃料のリサイクル計画の透明性を確保するとともに、計画推進のために必要な量以上のプルトニウムを持たないことを原則としています。

さて、原子力利用は、発電のみではなく、より広い分野でのＲ＆Ｄが重要と考えています。高温ガス炉は、将来の熱利用のために重要と考え、現在高温工学試験研究炉（ＨＴＴＲ）を建設中であります。原子力船については、原子力船「むつ」の実験航海で得られた知見と経験をもとに舶用炉の研究を続けています。放射線利用では、科学研究、医療、工業、農業などの分野で一層の発展が期待され、現在、イオン照射施設、大型放射光施設、重粒子がん治療装置などが建設中です。

（新たな原子力開発利用長期計画の策定）

従来、原子力委員会は、原子力開発利用長期計画（以下「長期計画」

という。）をほぼ5年ごとに数次にわたり策定してきています。

現行の長期計画は１９８７年に策定されたものであり、以来日本の原子力開発は、この長期計画をガイドラインとしてきました。しかし、現行長期計画策定以来５年余が経過し、この間、日本の原子力開発利用はおおむね着実に進展し、今後の展開について検討すべき時期にきており、一方で国際社会は激動の時代を迎え、冷戦の終了、核兵器の拡散に対する懸念の高まり、地球環境問題に対する意識の向上等全地球規模で大きく情勢が変化しています。このような内外の環境変化を踏まえ、２１世紀を展望しつつ日本がとるべき原子力開発利用の基本方針及び具体的推進方策を明らかにするため、原子力委員会は、昨年９月に新長期計画の策定作業を開始しました。

長期計画は、総合的な原子力政策を明らかにするものであり、我が国の原子力開発利用のあらゆる分野に言及することとなりますが、今回の主な検討事項としては、

・長期的展望に立った平和利用体系の構築

・核兵器不拡散と原子力平和利用との両立

・原子力分野における国際貢献の在り方

等が挙げられております。

第一の長期的展望に立った課題には次のようなものがあります。

エネルギー問題を長期に考え、２１世紀半ばまでを展望すると、この頃の世界の人口は１００億になると推定されています。開発途上国の生

活水準の向上が必要なことは言うまでもなく、一人当たりのエネルギー消費量は増加します。人口増加と一人当たりのエネルギー増加の両方から、グローバルなエネルギー消費は大幅に増加せざるをえません。しかし、石油や石炭などの化石燃料の消費を増やし続けることは、資源量からも地球環境保全からも許されそうにありません。

こう考えると、非化石燃料で長期に多量のエネルギー供給を行い得るものを、科学技術によって産み出すことが不可欠であることが分かります。その候補者として、原子力では、高速炉による核燃料リサイクルによる核分裂エネルギーと、核融合エネルギーがあります。いまだ研究段階にある核融合につきましては、従来もその研究に努めてきましたが、今後も国際協力を重視しながら進めていくつもりであります。

高速炉開発は、核融合に比べてずっとその開発が進んでいますが、まだ経済的競争力はありません。しかし、未来のエネルギーの重要な選択肢の一つでありますので、今日経済性が十分でないからといって放棄するのは賢明とは思いません。一方、このような長期のＲ＆Ｄを維持していくことは容易でなく、国際協力が重要であります。原型炉「もんじゅ」も国際協力に利用し、その成果を各国と分かちあうべきものと考えています。また、プルトニウムの需給状態に応じて、高速炉をプルトニウム、あるいはアクチノイドの燃焼に利用するのも良いことと思います。何となれば、現在および近い将来のわれわれの目的は、プルトニウムを増殖させることではなく、未来のエネルギーの選択肢を維持（ｍａｉｎｔａｉｎ）することだからであります。

第二の核兵器不拡散と原子力平和利用の両立でありますが、これは日本のみならず原子力平和利用を推進している各国にとって共通の希望であると思います。日本は従来から一貫して原子力を厳に平和利用に限って推進していますが、今後は日本の原子力開発利用長期計画について世界各国の理解がえられるよう努力することが一層重要になってきています。このため、日本の原子力活動の透明性を確保するとともに、世界の核不拡散体制の維持・強化に積極的に貢献する方策を検討する必要があると考えております。また、プルトニウムの管理に関する国際的な検討に積極的に参加する考えであります。

第三は国際貢献であります。原子力開発には安全確保が先ず重要であることは言うまでもありません。一つの大事故が、その国のみでなく世界の原子力開発に大きな影響を与えることは、既に経験したところであります。従って安全に関する経験と知識を分かちあっていくことは非常に大切なことと考えます。

また長期的目標のための大型の研究開発には、多くの人材と資金が必要であり、その成果は人類共通の財産となりますので、国際共同研究が望ましいと思います。米国、ＥＣ、日本、ロシアの４極によって行われている国際熱核融合実験炉計画（ＩＴＥＲ）はその良い例であります。

また、この原産年次大会に引き続いて１８日より３日間、世界原子力発電事業者協会（ＷＡＮＯ）の東京総会が開催される予定ですが、世界

の原子力発電の安全性向上に向けて、実りある総会となることを希望いたします。

さらに、このたび世界原子力学会協議会が発足し、本大会の機会に会合が持たれると聞いております。この学会協議会には、東京大学名誉教授の三島良績先生が副会長に就任、2年後には会長への就任が予定されているとのことでありますが、この学会の協議会が、世界の原子力平和利用の正当な発展に貢献されることを期待しております。

（おわりに）

我が国の原子力の開発利用を進めるに当たっては、平和利用に限定することと安全の確保が基本であります。私としてはこれらの基本を守り、適切かつ着実な計画の推進に努める所存でありますので、皆様方におかれましても、一層の御支援、御協力をお願いする次第であります。

本日から3日間、内外の有識者・専門家の方々の間で忌憚のない活発な意見交換が行われ、また貴重な提言がなされ、本大会が成功を収められんことを心から祈念して、私の所感とさせて頂きます。

以　上

第２６回原産年次大会開会セッション特別講演

「惑星的観点から原子力を考える」

英国学士院会員
ジェームス．Ｅ．ラブロック

まずは、ひとつ謙虚になるところからお話を始めましょう。人類をずっと遠くから、そう、地球全体として眺めてみましょうか。すると私たちは、ルイス・トーマスが言ったように、きっとアリ（蟻）のように見えるはずです。「彼らが人間そっくりなこととときては、まったくこちらが気恥ずかしくなるほどだ。彼らアリは、キノコを育て、家畜としてアリマキを飼い、軍隊を仕立てて戦争を行い、化学物質を噴射して敵に警告を発したり、これを撹乱したり、奴隷を捕まえたりもする。ツムギアリの一族ときては、幼年労働に励み、織り機の杼（ひ）のように捧げもった幼虫の口から出た糸で、木の葉を縫い合わせてはきのこの栽培所に並べていく。情報交換もおさおさ怠りない。まったく、人間がして彼らがしないことといったら、テレビを見ることくらいのものではないだろうか」

今日の私のテーマは、外から見た地球と地球人、空の高みから見おろした地球と私たち、というものです。私がこうした見方をするようになったのは、人間が宇宙に旅立つようになってからです。私は確信しているのですが、３０年前に始まった宇宙旅行は、人類最大の業績のひとつです。こうした宇宙旅行があって初めて私たちは、地球が限りある存在であること、そしてどれほど美しい星であり、姉妹である死の惑星の火星や金星とどれほどかけ離れているかに気づいたのです。そしてやっと、地球が必要としているものに気づかない限りは、人類に未来はないと理解し始めたのです。

<スライド１　地球と火星、金星>

宇宙から地球を眺めるようになって私がもう一つ変わったのは、超生命体として地球を考えるようになったことです。超生命体・・・つまり、自らの気候や大気を調節して、生命にとって常に快適な状態を作り出せる存在のことです。ガイアと呼ばれる地球の論理…これが私の今日の講演のテーマなのです。

では、まずこうしたガイア理論が生まれたころに戻って、どのようにこの仮説が生まれたかをお話しします。時期としては３０年ほど前、アメリカの航空宇宙局ＮＡＳＡからお声がかかって、火星の生物探査に加わってほしいと要請されたときのことです。それまでの私は、宇宙探検などＳＦの世界のものだと思っていたのですが、ＮＡＳＡの意図は真剣なものであるのがすぐにわかってきました。このＮＡＳＡの月および地球担当部門が目指している重要な目標の一つに、火星での生命の発見がありました。この仕事の関係上、カ

リフォルニア州パサデナにあるあの有名なジェット推進研究所を、短時間ですが訊ねる機会もありました。先方としては、私の力で感度の良い分析機器の設計製作を行ってほしかったわけですが、彼らと仕事を進めるうちに、火星上の生命の有無を探る彼らの方法に私の方が興味を覚え始めました。私は、ジェット推進研究所で優秀な技術や物理学の実験に出会ったわけですが、彼らの生物学的実験もそれと同じくらい優秀なものだろうと期待していたのです。しかし、そこで行われていた実験はまるで想像力を欠いたものでした。いや、それ以下でした。もし火星に生物がいたとしても、あんな実験ではほとんどわからなかったはずです。技術が高度になると起きる奇妙なことの一つに、エンジニアリング技術が洗練されればされるほど、最終的にそれが利用される先は、陳腐で取るに足らないものになっていくことがあります。衛星テレビで中継されるごく普通のテレビ番組はその好例であり、今回火星で行われることになっていた生物学的実験も似たりよったりだったのです。その実験の大半は、地球上の生物学実験所をただ機械的に火星用に置き換えただけのものであり、火星の生物も地球上の生物と同じものだと想定していました。たとえば、細菌学者は自動式の実験装置を火星に送ろうと提案しました。この装置で火星の土をすくいとって栽培容器に入れ、バクテリアの繁殖を観察しようというのです。こうした実験では生物が発見できない理由はいろいろありました。まず、火星に細菌は存在しないかもしれないこと。もし存在したとしても、その生化学的組成は異なっている可能性もあります。また、実験装置の着陸場所が、たまたま何もいない場所であるかもしれないこと。たとえ地球上でも、もし探査機が南極の氷山の天辺に着陸したら、やはり生物は発見できず、ということになってしまいますよね。だから私は、そのように狭い範囲にだけ焦点を合わせたり、還元主義的なアプローチをするのは止めて、火星全体として眺めたらどうかと提案したのです。生命の有無を探る実験で、もっとも簡単でもっとも一般的な方法は、大気の化学分析です。生物の存在しない惑星の大気は物理学と化学だけでそうとわかりますし、その化学的組成は、ほぼ化学的平衡を保っているものです。一方、生物のいる惑星では、地表の生物体が大気から生きていくための材料をもらい、大気に老廃物を貯めていかなくてはなりません。こうなると大気の化学的組成には変化が生じ、生命の存在を示すような形で不均衡が生まれるのです。そこでダイアン・ヒッチコックも加わり、私たちは共同で、赤外線天文学を利用して火星の大気を調査しました。この結果と、生物の存在が既に認められている惑星、すなわち地球で生物が生きていく源とし老廃物の捨て場としている大気とを比べたのです。この二つの惑星の大気にはびっくりするほどの違いがありました。火星の大気は化学的に平衡状態に近く、その大部分は二酸化炭素でした。これとまったく対照的に、地球の大気は化学的にひじょうに不安定な状態にあります。二酸化炭素はきわめて微量で、大量の酸素がメタンやそのほかの反応性の気体といっしょに混然と共存している状態は、限りなく化学的不均衡を呈し、これは生物のいない惑星ではおよそ考えられないことです。地球には窒素や水が豊富にある事実も、地球化学ではなかなか説明がつかないのです。こうした変則的な存在は、火星にも金星にも認められず、それが地球上に存在

するということは、とりもなおさず、その表面に生物がいることを示しているのです。化学から導き出された、おそらくは正しいであろう結論からは逃れようもありません。すなわち、火星には生命は存在しないのです。

しかし、私たちの出資者であるＮＡＳＡは、こんな結論を聞きたかったわけではありませんでした。彼らは多大な費用をかけて火星へ探査機バイキングを打ち上げて生物を発見しようとしていたのに、ここにきて私たちがそんなものはいませんと言い出したのですからね。さらに悪いことには、私たちはＮＡＳＡの資金で宇宙からの地球観測を行っており、地球には生物が認められるなどという結論を出していました。これは、宇宙計画全体を、批判していると取られても仕方のない行為でした。彼らは訊いてきました。今さらそんな発見をして何の価値があるのですか？　私は悪びれもせずに、価値は大いにありです、と答えました。地球は生物の存在する星であるとの観点に立てば、ごく自然な質問として、では地球の大気はどうなっているのだろうという疑問が湧いてくるわけですが、ＮＡＳＡは図らずもこうした雰囲気を初めて作り出していたのです。これまでは、大気をこのように考えた者はいませんでしたし、地球とはなんと奇妙で美しい例外的な惑星なのだろうと改めて考える機会もありませんでした。私たち地球に住む者は、大気の化学的組成は安定していて当たり前だと思い込んでいます。たしかに組成は変化しているのでしょうが、各気体の存在時間に比べれば、その変化のスピードはずっとゆっくりとしているからです。地球の大気は反応性のガスの混合物なのに、なぜ、その組成が何か目に見えない作用で常に安定しているのか、などと不思議に思った者は誰もいなかったのです。１９６５年のある日、カリフォルニアのジェット推進研究所にいた私は、一定していながら、ひじょうに不安定、という地球の大気の矛盾に思いを致しているうちに、ある考えを思いついたのです。こうした安定状態が存在する以上、何か能動的な制御システムの存在があるはずではないでしょうか？

当時の私には、制御システムという自然観はまだ無く、ただ、地表の生物は地球の一部だという考え方があるだけでした。天体物理学者から聞いたことによると、星は年をとるにつれて放射する熱が増え、太陽も、その生命誕生以来、光度が２５パーセント増しているそうです。そこで私は、長い目でみれば、気候の調節も行われているかもしれないと気がつきました。私の中に、はっきりとした考えがまとまってきました。地球という星と、そこに住む生物すべてを含めた制御システムがあるはずなのです。６０年代の終わり頃、私はこの仮説を近所に住む小説家のウィリアム・ゴールディングと話し合う機会を得ました。それほど力に満ちた存在に名前をつけるとしたら、ガイアしかないと彼は教えてくれました。これからほどなくして私は、アメリカの優れた生物学者であるリン・マルグリスとガイアに関する共同研究を開始し、今日もこの共同研究は続いているのです。

では、ガイアとは何なのでしょうか？　ガイアとは、古代ギリシャ人が大地の女神につけた名であり、地理（ジオグラフィー）や地質学（ジオロジー）という言葉の語源になっています。大地の女神ガイアは、優しく母性に満ち、慈しみを与えてくれますが、越えて

はならない一線を越えた者には限りなく非情な顔を見せます。ガイアとはまた、地球と地球に住む生物に関するわかりやすい理論でもあります。生命にとって地球が常に快適な環境であるように気候や化学的組成を調整する機能が地球には備わっていることを前提とした理論なのです。そしてこの理論は検証可能であり、密接に関連したいくつかの微分方程式という数学的にも正当なる基盤があります。このガイア理論で地球の活動の仕組みがうまく説明できるかどうかはまだわかりません。まだ証拠が一部しか集まっていないからです。今の段階でのこの理論の価値は、私たちが地球を考えるときに、今までと違った見方ができることだと思っています。人類の利益だけが問題なのだろうか、と私たちに考えさせてくれることが、現時点のガイア理論の価値なのです。もし、大地の女神ガイアがほんとうに存在するのならば、彼女はきっと私たちの前にその姿を現してくれるはずです。彼女なしには私たちは生きてはいけないのですから。科学のレベルで考えれば、ガイア理論は、新しい地球観を与えてくれます。今まで思いもよらなかった疑問を投げかけ、既にいくつかの重要な発見にもつながっています。

ガイアという考え方は新しいものではありません。初めて提唱されたのは２００年も前、提唱者は地質学の父、ジェームズ・ハットンです。彼は１７９５年にこう言っています。「地球は超生命体であり、これを正しく研究するには生理学が必要である」彼のこの賢明なる意見も、１９世紀には・・・科学が大いに発展したものの、その成長は樹木のようで、どんどんと細かく枝分かれしてしまった時代である１９世紀には・・・すっかり忘れ去られてしまいました。ハットンの考え方やガイアといったものは、広範囲に渡る一般教養的な科学であり、極度に専門化した今日の科学では理解し得ないものなのです。ガイア理論とは一種の進化論であり、そこでは素材としての地球とそこに生きる生物が、密接に関連した一つの過程に沿って進化していきます。ダーウィンの自然淘汰の考え方ともぴったりと一致します。地球が気候と化学的成分を自分で調整できるというのは、緊急時になると自動的に発動する特質なのです。調整には、まったく将来の見通しも計画性もありませんし、何の目的論もそこには関与していません。科学者として私は、自分の理論は正しいはずだなどと独断的に言うことだけは絶対に避けたいと思います。ですから、ガイア仮説も正しいかどうかは今の私にはわかりません。ただ、時間と実際の証拠だけがその答を教えてくれるのでしょう。

私はどこにも属さず、もの書き兼発明家としての収入だけで、このガイア理論を発展させていきました。３０年前の時点で、大学や政府の研究所でこんな仕事にとりかかっていたらどうなっていたかを考えておいたのは、なかなか賢明なことでした。おそらく研究させてもらえたはずはありません。第一、研究費が認められるはずがありません。ガイア理論はあまりにも大きな賭に思われたからです。それでもあきらめずに自分の昼食時間や空き時間に続けていると、そのうち研究所の所長から呼び出しがかかるでしょう。そして彼のオフィスでこう言い渡されます。そんな不人気な研究課題に関わっているようでは、君の学者としてのキャリアに傷がつくよ。こんな忠告も物かは、頑固にガイア理論にしがみ

ついていると、再び呼び出しがかかって、今度ははっきりとこう言われるのです。君のせいでこの部門全体の評判が傷つきかねないんだ、それにもっと困ったことには、私自身のキャリアにも傷がつくんだよ、と。私にまだ運があれば、彼は定年前の退職の申請方法を書いたちらしを渡されたかもしれませんね。

ガイア理論など何の役に立つのですか？　この理論は科学にどんな貢献をしてきたのですか？　こうした質問が出るのも当然です。現役の科学者が新しい理論を判断するときの基準は、その理論による予測がどの程度実際の役に立つかにあります。この基準によれば、ガイア理論は、導入当初から地球科学に3つの進展をもたらしてきました。まず1つめはヨードと硫黄についてで、この2つの元素はまずヨー化メチルと硫化ジメチルという気体で大気中を移動し、この何れも海面近くに生息する海草が自然に作り出すものだという発見です。私がこの発見をしたのは、小舟でイギリスと南半球との間を往復していたときのことです。航路のいたるところで、こうしたガスが発生して海洋環境の一部になっているのがわかりました。この航海以前には、科学者は間違って、ヨードと硫黄は海水中の塩分が霧のようになることで大気中を移動していくと考えていました。彼らの意見によると、生命体は地球の組成を調整するのに何の役も果たしておらず、人間はわけのわからない無機化学がぽんと投げてよこす化学製品をただ回転させて消費しているだけだというのでした。ガイア理論が科学にもたらした2つめの進展とは、地球の気候を長期的に考えると、地面に生えた植物が二酸化炭素を吸収することで、きちんとこれを管理しながら制御しているという発見でした。

<スライド2　地球化学的にみた岩石の風化>

二酸化炭素ガスの発生源はたったひとつしかありません。火山が噴火によって地球の中身を外に噴出させることだけです。二酸化炭素を吸収する方法も、長期的に考えれば、たったひとつしかありません。珪酸カルシウム質の岩石を風化させることで、大気中から取り除くことだけです。地球化学者はこれまで、風化は純粋に無機的な過程であり、そこには生物はいっさい関与しないと考えてきました。私は、同僚のマイケル・ウィットフィールドとアンドリュー・ワトソンとともに、生物が介在すると風化現象は少なくとも30倍のスピードで進行すると主張してきました。この主張は、アメリカ人科学者シュワルツマンとフォルクの実験によって、正しいことが実証されました。つまりどういう意味かと言いますと、生物が大気中の二酸化炭素の量を調節し、ひいては気候を調節するというのです。気温が低いと、土壌の植物の生育は遅く、二酸化炭素の吸収も遅くなり、結果的に大気中に二酸化炭素がたまって地球は暖かくなっていきます。気温が高いと植物がよく育ち、どんどん二酸化炭素を吸収して地球を冷やしていきます。太陽からのエネルギーはその誕生以来25パーセントも増大しているのに地球は暑すぎず快適なのは、こうしたプロセスからも説明できます。しかし、こうした植物のポンプが今現在どのように働いているかと

なると、頭をひねる問題が出てきます。現在は氷河期よりずっと温暖ですが、二酸化炭素は増大してきています。調整機能が働いているなら、減るか、そのままであるはずなのに、そうではないのです。これはいったいどうしたことなのでしょうか？

この答を出す前に、ガイア理論がもたらした３つめの発見のお話をしましょう。これも今の疑問の説明になりますからね。気体のジメチル硫黄は、硫黄をこれが豊富な海洋から、不足して必要な場所へと運んでいくという働きだけでなく、もっとはるかに大きな仕事をしていることがわかってきました。硫化ジメチルは空気中で酸化して、強い酸性の物質である硫化メタン酸、略してＭＳＡを作り出すのです。雲の粒は核となる粒子のまわりに集まってできるわけですが、この酸はこうした核の主要な発生源として知られています。海洋植物が硫化ジメチルを作り出さなかったら、雲は小さく薄くなってしまい、地球はぐんぐん暑くなってしまうでしょう。この研究は、同僚の科学者ロバート・チャールソン、アンディ・アンドリュー、スティーヴン・ワレンらと共同で行ったもので、８７年に論文を発表しました。ここでも、海洋植物と気候との関連をさぐってみようと思い立ったのは、ガイア的発想ゆえでした。海草が硫化ジメチルを作り出すのは、地球が暑くならないように働くガイア的なフィードバック機能の一部ではないだろうかと考えたのです。実際の証拠を集めていくと、結果は、調整どころかその正反対、気候を不安定にさせる傾向があることがわかったのです。いちばんショックだったのは、南極大陸で採取した氷山の中心部分を化学的に分析した結果です。これらから考えると、地球は最後の氷河期以来、温暖化しており、それにつれて氷に含まれるＭＳＡの量は減少しているのです。ということは、地球が暖かくなればなるほど雲は減り、ますます暑くなっていく、という意味なのです。二酸化炭素の謎と同じように、ここにもどんどん温暖化させていくという正のフィードバックが働いているわけで、ガイア理論でいう気候の自動制御とはまったく逆になってしまうのです。

<スライド３　氷山の中心部にみる二酸化炭素とＭＳＡの数値>

私は科学者になりたての頃にこんなことを学びました。検証中の理論と矛盾するように思われる証拠こそ、最終的にはその理論の正しさを立証するものだということです。検証する人間にとってむしろ注意すべきは、どちらにもとれる証拠、あるいは不確定な証拠なのです。明らかに矛盾しているというのは、ただ間違った方向から問題を眺めているにすぎなかったという場合もあるのです。今の例でいきますと、地球が現在一時的にうまくいかない状態にあるだけだと考えると、正の方向へのフィードバックも予想されない事態ではありません。ほら、この前、熱を出したときのことを思い出してごらんなさい。熱が出始めると、ふだんは体を冷やす方向に働く発汗作用ですとか皮膚の血管の拡張といった作用が機能を停止してしまいます。がたがたと震えがくることでも、さらに熱が発生します。これらはすべて、病気に特有の、正の方向に働くフィーバクです。しかし、元通り元気に

なれば、体温の調節機能がきちんと働くことを疑う人はいませんね。

今、地球を熱の出た病人だと考えれば、気候と二酸化炭素の間に働く正方向のフィードバックも、また気候と雲の量の間に働く正方向のフィードバックも納得がいきます。しかし、こんなふうに地球を病人扱いすることを正当化してくれるものがあるでしょうか？
まず注目すべきは、現代の地質年代である洪積世では、気候は大部分の時期が寒かったという事実です。現在のように間氷期に当たる時期は全体の１０分の１ほどしかないのです。さらに、南極の氷が記録しているのは、氷河には、現在より７倍ものＭＳＡが含まれているという事実です。さらに言えば、二酸化炭素は氷河期には、２００ｐｐｍも少ないのです。このどちらの事実も、現在よりもっと豊饒な、あるいはもっと活気に満ちた生物圏の存在を指し示しています。おそらく地球としては、冷たいままでいたいわけで、現在の間氷期は、私たち人間には快適ですが、地球自身に関して言えば、熱が出ている状態なのです。

以上の考え方を検証するために、私と同僚のリー・クンプは、ガイア理論に基づいた数量モデルを作りました。このモデルでは、地表では植物が二酸化炭素を吸収していますし、海中では海草が繁殖して雲という覆いを作り出しています。植物の生育に最適の気温は摂氏２２度、海草の生育に最適の海水の温度は摂氏１２度と仮定しました。これは海草の生育最適温度が地上の植物と異なっているからではなく、地球物理学的な理由から、海水の温度が摂氏１２度を越えると、海水の表面近くを暖流が常に流れているという現象が発生することからなのです。こうした海流ではすぐに養分が不足し、海草の繁殖が止まってしまうのです。私たちのモデルは、氷河期の涼しい状態での気候の自動制御を予言していました。海草によって雲が形成され、また地表では植物によって二酸化炭素が吸収され、何れも温度上昇に対して負の方向に働き、気候を安定させたのです。そして、もう一つこのモデルが見せてくれたのは、安定化の方向にぎりぎりまで進むと、太陽からの熱がほんの少し増えただけで、温暖化・不安定化の方向にどんどん進み出してしまうことでした。この切り替えの時期の前後では、全体に対しては正の方向のフィードバックが働きました。

地表の植物と海中の海草の生育状況を知るために人工衛星から地球の写真を撮ると、海草が盛んに繁殖しているのは北極と南極のまわりの海と、大陸周辺の海水が湧き出ている地域だけに限られていて、どちらの水温も摂氏１２度以下であることが確認できます。

＜スライド４　海草が繁茂する地域の限界を示すために、太平洋の写真＞

１年の大半の気温が２２度を越える北緯３０度と南緯３０度の間の地域は、砂漠か熱帯雨林の何れかです。こうした森林は不安定で、一度伐採されると二度と回復しないのは周知の事実です。また、この熱帯雨林は自分が生育する地域の気候を司る生態系でもあり、気温が上昇すればおそらくは生育は遅くなっていくだろうこともわかっています。先ほどのモデルとこうした現実は、ガイア理論でいう長い目でみた自己制御と一致しますが、現

在の発熱状態の地球にあっては、理論に反した証拠になってしまいます。氷河期から間氷期への移行の直接の原因は、地軸の傾きや公転軌道上の太陽に対する地球の位置の周期的な小さな変化、いわゆるミランコヴィッチ効果、にほぼ間違いないと考えられます。太陽から受ける熱の上昇それ自体は、氷河期から間氷期へという大きな気候の変化のきっかけとなるには不十分なのです。ミランコヴィッチ効果が、こうした移行の主たる原因ではないものの、きっかけとなったのです。

現在の気候をこのように地球的規模でとらえた考え方が正しいとしたら、私たち人間は実にまずいタイミングで、温室効果ガスを大気中に放出したり、地表に自然に生えていた生態系を農業用に利用し始めてしまったものです。さらに事態は深刻なことに、人間のこうした行為の結果は、先ほど説明した正の方向へのフィードバックによってますます増幅され、来る２１世紀の気候は予想より暑くなってしまう恐れがあるのです。

＜スライド５　地球の温暖化の影響を説明するモデル＞

私はこの講演の冒頭で、宇宙旅行のすばらしさを誉めたたえ、ガイアの再発見につながった経緯をお話ししました。私の実感では、もしも超大国である米ソ間の冷戦がなかったら、あの時期に宇宙探検は実現しなかったでしょう。あれだけの膨大な経費をまかなえるのは、おそらく軍事予算だけなのです。

宇宙探検は、政治家や科学者からすれば、人間中心主義の顕示でした。人類が初めてほかの惑星にしるした領土進出の第一歩でした。彼らの言葉には傲慢さがあふれています。地球で共存していく方法も、あるいは地球とうまく折り合いながら生存していく方法も知らないくせに、火星を地球化して人類の第二の住みかにしようなどとは、何という傲慢さでしょうか。宇宙の植民地などとは、何という馬鹿げた途方もない考えではないでしょうか。こんな破天荒な考えを思いつくのは、自分のことを征服の旅に出た宇宙船の船長だとでも思っている人間だけです。彼らは、新たなるフロンティアを求めて闘志満々ですが、自分があとにしてきた故郷の荒廃ぶりにはまるで気がついていないのです。そうした彼らの物言いと、月に向かって飛んでいった勇敢な宇宙飛行士たちの言葉には、はっきりとした違いが見られます。彼ら月へ行った飛行士は、畏敬の念を抱かせるほどの宇宙の広大さと、地球の小ささを知り、その地球こそが自分たちの故郷であるという事実を身に沁みて実感したのです。ジム・ラヴェル・・・もう少しで帰らぬ人となったかもしれない３人のうちのひとりですが、その彼がこんな話をしてくれたのを私は今でもよく覚えています。月から見ると、腕を一杯に伸ばした親指の爪で地球は隠れてしまう、という話です。

宇宙旅行はまた、宗教と科学の力関係も変え、地球や宇宙の神秘を説明しようとする科学の権威を高めました。月面を人間が歩いたという事実の前には、純朴な人々も宗教の迷信的な面ですとか、独断的な面には信仰心を持たなくなりました。１９６９年、人類が初めて月面に降り立ったとき、私は家族とアイルランドの西の端にいました。当時のヨーロ

ッパで、最も美しく、最も人間の手が及んでいない、最も信仰心の篤い土地です。あの着陸から1週間というもの、人間が月に着陸したなんてほんとうですか？と訊きに、土地の人が次々にやってきました。もちろんですとも、ラジオで聞きませんでしたか？と答えますと、もちろん聞きましたとも、でもあなたの口からほんとうだって聞かなくては気が済まなかったのです、と言うのです。なぜですか？と言うと、彼らはこう答えました。「私たちは、ほんとうのことを知りたいのです。空のずっと上には、天使もいなければ天国もなかったと知りたいのです」

実際のものであれ、頭の中のものであれ、あの宇宙旅行のほんとうの価値とは、地球の真の姿を知り、それによって、人間主義の礼賛だけでは不十分だと気づいたことなのです。宇宙から眺めれば、私たち人間はより大きな存在である地球の一部であることがわかりますし、その存続も安寧も分かち難く地球と結びついていることも見えてきます。やがて時がたてば、私たちがものを考える基準は、銀河系から全宇宙へと広がっていくことでしょう。しかし、目下の所は、地球にすべての注意を向けなくてはなりませんが・・・。

地球的な視点に立って考えることの必要性、巨大科学が言い立てることに疑いを抱くことの必要性を、私は今までお話ししてきました。世界的に資金が減らされている今、科学者の集団は分断され、自信を失っています。科学者だって人の子です。最大の関心事は自分の仕事であり、年金であり、生活の保障やそのほか近代的な都市生活を送るのに必要なあらゆる事項です。また、実施義務のない事柄に自ら責任を負おうとするのも難しいことです。ということはどういう意味かといいますと、科学者としてアドバイスをする者も、自分では客観的になっているつもりでしょうが、やはり自分の属する科学者集団の欲求なり偏見なりに左右されるということなのです。

この結果、科学者がよく提示する優先事項のリストにも、その科学者集団の目下の優先事項が反映しているわけで、それは一般の人々にとっての優先事項でもなければ、ましてや地球にとっての優先事項などではあり得ないのです。

だからこそ、地球にとって危険なことを重大な順に挙げたリストは、最近まで次のようになっていたのです。第1位、原子力。原子力発電所だろうと処理施設だろうと廃棄物処理だろうと原子爆弾だろうと、ともかく原子力は危険だというのです。第2位、オゾンの減少。第3位、化学工業から出た廃棄物。言い替えれば、3位までのすべては人間にとって発癌性や突然変異誘発性をもったものであり、科学者ならば容易に計量できるものなのです。温室効果をもたらす大気中の微量ガスですとか、二酸化炭素やメタンといった地球を脅かす汚染物質、熱帯雨林の伐採などのもっと大きな危険が、行動を起こすべき事項にのぼってきたのは、やっと最近なのです。

しかし、ガイアを通じて眺めてみると、物事は一変します。私に言わせれば、最大の、そして緊急の、そして確実な危険の原因は、熱帯の森林の伐採と温室効果ガスの蓄積なのです。

湿潤な熱帯は人間の居住地であり、生理学的にも重要な生態系です。私たちはこの居住

地を無惨なスピードで破壊しているのです。しかし、第一世界、つまり西側先進諸国で熱帯の森林保護を訴えるとき、その根拠は実に脆弱なもの・・・つまり熱帯の森林は珍しい動植物の宝庫だから、というものであり、あまつさえ、癌に効く成分を含んだ植物が生えているから、などというものもありました。たしかに嘘ではないでしょう。大気中の二酸化炭素を吸収するのに若干の効果はあるでしょう。しかし、熱帯の森林のしてくれることは、もっともっと大きいのです。森林は多量の水蒸気と、雲の形成を助けるガスや粒子を排出する能力によって、白く輝く雲という日傘をさし、その雲から自分たちを生かしてくれる雨を降らせることで、この地域を涼しく潤った状態にしているのです。これと同じだけの空調と潅漑を行うのに必要なエネルギーという観点から、こうした森林の価値を計算しようと思えば、簡単なことです。年間５００兆ドル、６０００兆円のさらに１０倍、という値です。しかし人間は毎年、イギリスに相当する面積の森林を焼き払い、あとにできるのはたいていが粗雑な牧場です。こうした牧場は、温暖な土地のものと違って、すぐに砂漠と化してしまい、さらに木々は伐採され、大地は焼き払われていくことになるのです。私たちは、自分がどんなにひどいことをしているかに気づいていません。熱帯の森林の７０から８０パーセント以上を破壊してしまったら、残りの森林ではもはやそこの気候は維持できず、生態系全体が崩壊してしまうのです。現在のスピードで伐採が進んでいったら、森林が自分たちを維持していくのに必要な量を失ってしまう日もそう遠くはありません。森林が消滅してしまったら、そこに住む１０億もの貧しい人々は、何の支えもなく放り出されてしまいます。これは規模で言えば、大型の核戦争よりもっと巨大な脅威です。そんなことになったら、多くの人がどれほど苦しみ、どれほどの難民が生まれるか、罪の大きさと政治的な影響を考えてごらんなさい。しかも、第一世界にいる私たちが、森林の伐採によってさらに激化している温室効果という思いもかけなかった災害と戦っているのと同時に、こうした事態が発生するのです。とても力を貸してあげられるどころではありません。

地球の人口が初めて２０億を突破したのは１９３０年のことでした。以来私たちは、今のような生活を送ってきたのですから、長期にわたって地球がわれわれに与えてくれる以上のものを地球から奪い取ってきたことになります。人口が５０億を越えたならば、たとえ人類全員が菜食主義者になり、食べ物を等しく分け合ったとしても、もはや地球は私たちすべてを養うことはできなくなるという計算があります。すでに現在の人口は５５億、ロードアイランド大学の世界飢饉計画にあるこうした数字は、笑いごとではありません。

哲学的必要協議事項のトップに自分たち人間の利益を掲げ、地球を無視し続けるならば、地球はきっと大きな歴史的転換点を迎えるでしょう。社会的知性に富んだ最初の存在である私たち人類に、原因を作り、経過を見守る特権が与えられるのです。差し迫った変化と言えば、気候が変わることであり、その変化の大きさは、少なくとも氷河期から現在までの変化の大きさに相当するものです。

この目前の変化の大きさをつかむために、数万年前の最後の氷河期まで戻ってみること

にしましょう。すると、氷河は北アメリカでは北緯３５度まで、ヨーロッパではアルプスまで南下しています。海面は今よりも１００メートルは下にありますから、アフリカに相当する面積の大陸が水面上にあって植物に覆われています。当時の熱帯は、現在の温帯と同じでした。全体としてみれば、現在より暮らしやすい場所であり、土地もたくさんありました。

さて、目の前に広がったこの光景を理解するには、逆に温熱期とでもいう時代を考えてみましょう。氷河期が現在よりずっと寒い程度に、現代よりずっと暑い時代です。気温も水位も上がり、やがて世界は炎熱地獄となって、氷河も溶け、何もかも見分けがつかなくなります。ただ最終的にこうなるまでは多大な時間がかかり、おそらくこんな事態にまではならないかもしれません。つまり、目下、私たちが心構えをしなくてはならないのは、こうした事態になるまでのできごとそのものであり、今起ころうとしているできごとなのです。こうしたできごとは、おそらくは驚異のできごとであり、最新鋭の科学のモデルがどんなに精密に想定してもまず予測できない事態でしょう。たとえば、オゾン・ホールを考えてみましょうか。これはまったく思いもかけないできごとでした。最高級のコンピュータが地球のオゾン層のモデルを想定し、監視を行っていても、観察もできなければ予測もつかない事態でした。これを見つけたのは、簡単な道具で空を眺めていた人でした。驚異のできごとは、気候的極相のごとく、つまり大嵐のように、あるいは突発的な大気中の現象のようにやってきます。自然とはけっして直線的に進むものでも、予測できるものでもなく、ましてや移行期となればますますこの性格は顕著になるのです。

今、私たちはガイアに助けを求めることはできません。もし現在の間氷期がほんとうに地球の発熱期であるならば、今の地球にできるのは安静にしてもとの健康な氷河期に戻ることだけです。しかし、こうした安静は望むべくもありません。私たち人間が牧場にしようと地表をむしりとっているからで、特に熱帯雨林・・・放っておけば、何より地球が健康を回復する手段であるはずのこうした森林・・・のむしり方はひどいものです。さらに私たち人間は、ただでさえ熱の高い病人に、温室効果による厚い毛布をかけようとしています。こんな具合では、ガイアはがたがた震えながら、別のもっと手に負える生物相にふさわしい新たな安定状態に移行していくかもしれません。それはもっとずっと暑い世界かもしれませんし、いずれにしろ、今より住みやすい世界であるはずはありません。これはただのお話の世界の破滅へのシナリオではなく、辛い限りですが、現実に起こりそうなことなのです。最近の地質年代だけでも私たち人間は、環境を変え、予測不能な事態にまで追い込んでしまいました。私のせいで、文明はまわりを汚染しながら坂道を転げ落ち、その先はぐんぐん水位が上げながら人間を溺れさせようとしている海なのです。

私たちの地球が少なくとも自分たちと同じくらいたいせつなものであると気づかずにいたら、こうしたやりきれない予言は現実になるほかないでしょう。今、未来は、世界の中でのこの中心的部分がどんな決断を下すか・・・すなわち、エネルギーの供給と技術の進歩が最も急速に進んでいるこの地域がどんな決断を下すかにかかっています。私たち人類

の未来は、アジア大陸の東に位置するあなた方が、地球を傷つけずに、ひいては人間を滅ぼさずにエネルギーを利用する方法を発見することにかかっているのです。こうした観点からすると、原子力エネルギーは、化石燃料を燃やすのに較べれば地球に及ぼす害は遥かに少ない・・・私はそう考えています。

私は、どんな集団にも属さない科学者としてお話ししてきました。しかし私とて一個の人間です。自分の孫たちにはまだまだ未来のある世界で成長していってほしいと願います。しかし、私の仲間達は、現在空席になっているある組合の代表の仕事をやれと私に押しつけてきました。組合員は全員人間以外の生きもので、バクテリアだとか、虫だとか、いささか見かけはぱっとしない仲間ばかりです。この仕事は断るわけにはいかないでしょう。人間の代弁者はたくさんいますが、彼らの・・・地球が生きていく上で、人間よりもずっと頼りにしている彼らの・・・代表として意見を言う人間は滅多にいないからです。

イギリスの郊外にある私の実験室からは、夜になると星や天の川が見えます。昼間には、鳥のさえずりが聞こえ、大地のにおいがします。こんなふうに地球を見、地球を感じ、地球を一個の生命体として考えるようになると、私たちの心と頭は、人間が環境に対してもっとも関心を抱かなくてはならないこと・・・すなわち、地球そのものを慈しみ守っていくことであり、とりわけ、湿潤な熱帯地方の森林を守ること・・・に向かっていきます。人間のことだけを心配していては足りないのです。この地球上に暮らすどんな人間にも、たとえ人類という単位で考えても、終身存続権などはないのです。私たちが地球に対する責任を認識しない限り、本来与えられた寿命すら全うできないでしょう。ですから、けっして急ぎすぎないように。そして、健康で美しい世界、私たちの子孫にとってもまた、この地球ガイアに生きるパートナーの孫たちにとっても快適な住みかであり続ける世界を目指して進んでいこうではありませんか。

A planetary view of nuclear power.

by James E. Lovelock

I want first to put us in our place. If we look at humans from far away, from a planetary perspective we are, as Lewis Thomas once said, like ants. "They are so much like human beings as to be an embarrassment. They farm fungi, raise aphids as livestock, launch armies for wars, use chemical sprays to alarm and confuse their enemies, capture slaves. The families of weaver ants engage in child labour, holding their larvae like shuttles to spin out the thread that sews the leaves together for their fungus gardens. They exchange information ceaselessly. They do everything except watch television."

My talk today is about the Earth and people as seen from outside, the top down view. This view came from our journeys into space. I do believe that those voyages outside the Earth thirty years ago were one of our greatest achievements. They made us aware for the first time that our world was really finite and let us see how beautiful and different it was from those barren dead sister planets Mars and Venus. We then began to understand that unless we recognised the needs of the Earth, humans had no future.

Slide 1 Earth Mars and Venus.

The view from space also led me to see our planet as if it were a superorganism, something able to regulate the climate and atmosphere so as always to be comfortable for life. This theory of the Earth called Gaia will be the theme of my address.

Let me go back to the beginning and tell you how it started some thirty years ago, when in 1961 the American space agency NASA invited me to join with them in their search for life on Mars. Before that I had considered space exploration to be science fiction, but I soon discovered that their intention was serious. An important goal of the Lunar and Planetary Division of NASA was the search for the presence of life on Mars. The work involved brief visits to that famous institute, the Jet Propulsion Laboratories, in Pasadena, California. They wanted me for my ability to design and make sensitive analytical instruments, but soon after joining them I became interested in their methods for detecting life on Mars. I expected that the biological experiments would have the same excellence that I found in the exquisite engineering and physics of the JPL. Instead I found the biological experiments unimaginative. Worse, they almost certainly would not have worked even if Mars had life. One of the peculiarities of high technology is that the greater the quality of the engineering the more banal and trivial is its final use. Such is the usual nature of programs transmitted by satellite television, and so it was with the biological experiments to be sent to Mars. Most of them were an automated version of the biologists laboratory here on Earth and assumed that life on Mars would be the same as here. The bacteriologists, for example, proposed sending an automated laboratory to Mars. It would scoop a sample of Martian soil and apply it to a culture plate and look for the growth of bacteria in the soil. There were many reasons why such experiments could fail to detect life. Martian life might not include bacteria; even if it did the biochemistry might be different. The experiment might land at a barren site. Even on the Earth if the experiment landed on a polar ice cap it would not have found life. I suggested that instead of so narrowly focused and reductionist an approach, they try a top down view of the whole planet. The simplest and most general life detection experiment would be the chemical analysis of the Martian atmosphere. A lifeless planet would have an atmosphere determined by physics and chemistry alone and the chemical composition would be close to the chemical equilibrium state. But on a planet that bore life, the organisms at the surface would be obliged to use the atmosphere as a source of raw materials and as a depository for wastes. Such a use of the atmosphere would change its chemical composition. It would depart from equilibrium in a way that would show the presence of life. Dian Hitchcock joined me then, and together we examined atmospheric evidence from the infrared astronomy of Mars. We compared this evidence with evidence about the sources and sinks of atmospheric gases on the one planet we knew bore life, Earth. We found an astonishing difference between the two planetary atmospheres. Mars <u>was</u> close to chemical equilibrium, and its atmosphere dominated by carbon dioxide. The Earth's atmosphere in great contrast is in a state of deep chemical disequilibrium. In our atmosphere carbon dioxide is a mere trace gas, and the coexistence of abundant oxygen with methane and other reactive gases shows a near infinite degree of chemical disequilibrium, something impossible on a lifeless planet. Even the abundant nitrogen and water of the Earth are difficult to explain by geochemistry. No such anomalies are present in the atmospheres of Mars or Venus, and their existence in the Earth's atmosphere signals the presence of living organisms at the surface. There was no escaping the probable conclusion of chemistry: Mars was lifeless.

This was not the news our sponsors NASA wanted to hear. They were preparing at great expense the Viking space craft to go to Mars to find life and here were we saying there was none there. Worse than this, we had used NASA funds to view the Earth from space and conclude that there was life on it, something that could have led to the criticism of the whole space program. They asked me, what could possibly be the value of such a discovery? I was unrepentant and answered that I saw great value in it. They, NASA, had unintentionally set up an environment in which it became, for the first time, natural to ask questions about the nature of the Earth's atmosphere in the context that it was a planet with life upon it. No one had looked at the atmosphere this way before and had the opportunity to see what a strange and beautiful anomaly is the Earth. We who live on Earth take for granted the steady constant chemical composition of our atmosphere. Changes do occur but only slowly compared with the residence times of the gases. No one had wondered how our atmosphere could remain constant and stable in composition by blind chemistry when it is a mixture of reactive gases. One afternoon in 1965 at the JPL in California, when thinking about the contradiction of our constant but highly unstable atmosphere, the thought came to me in a flash that such constancy required the existence of an active control system.

Then, I lacked any idea of the nature of the control system, except that the organisms on the Earth's surface were part of it. I learnt from astrophysicists that stars increase their heat output as they age and that our Sun has grown in luminosity by 25% since life began. I realised that in the long term there might be climate regulation also. The notion of a control system involving the whole planet and the life upon it was now firmly established in my mind. Sometime near the end of the 1960's I discussed this idea with my near neighbour the novelist William Golding. He suggested the name Gaia as the only one appropriate for so powerful an entity. Not long after this I began a collaboration on Gaia with the eminent American biologist, Lynn Margulis, that has continued until now.

What is Gaia? Gaia is the name the ancient Greeks gave to their goddess of the Earth and is the root of words like geography and geology. The goddess Gaia was at once gentle, feminine and nurturing, but also ruthlessly cruel to those who transgressed. Gaia is also a straightforward scientific theory about the Earth and the organisms that inhabit it. A theory that postulates the ability of the system to regulate the climate and chemical composition so that the Earth is always a comfortable habitat for life. A theory that is testable and has a proper mathematical basis in a set of closely coupled differential equations. We do not yet know if it is a good explanation of the way our planet works; the evidence is only partially gathered. I see its main value at this stage is to provide a different way to look at the Earth. A way that forces us to question whether the good of humankind is the only thing that matters? If Gaia does exist then it must come before us for we cannot live without it. At the scientific level Gaia theory provides a new way to look at the Earth. It asks new questions and has already led to significant discoveries.

The principles of Gaia are not new, they were first proposed over two hundred years ago by the father of geology, James Hutton. He said in 1795 "I consider the Earth to be a superorganism and its proper study should be by physiology." His wise words were forgotten in the next century when science flourished abundantly, but also grew like a tree and separated into many separate branches. Hutton's view and Gaia are broad general science and almost incomprehensible in the overspecialised science of today. Gaia is an evolutionary theory that includes the material Earth and the organisms in a single tightly coupled process. It is entirely consistent with Darwinian natural selection. The self regulation of the climate and the chemistry of the Earth is an emergent property that arises automatically. Regulation goes on entirely without foresight or planning and there is no teleology involved. Let me say that as a scientist I wholly reject dogmatic certainties. I don't know if Gaia theory is right; only time and evidence will bring an answer.

I have developed Gaia theory as an independent scientist funded from my income as a writer and inventor. It is useful to consider what might have happened had I tried to work on it, thirty years ago, in a university or a government laboratory. It would have been almost impossible. To start with, there would be no funds approved. Gaia would be considered much too speculative. If I had persisted and worked in my lunch hour or spare time, it would not be long before I received a summons from the laboratory director. In his office he would have warned me that my career would suffer if I persisted in so unfashionable a research topic. If this did not work and obstinately I continued to work on Gaia, he would have summoned me again and stated firmly that my work endangered the reputation of the department, and more important his own career. If I were lucky, he would have handed me a leaflet on how to apply for early retirement.

It is right to ask what is the use of Gaia theory? What has it done for science? Working scientists usually judge a new theory from the usefulness of its predictions. By this measure Gaia research has led to three advances in Earth science since its introduction. The first was the discovery that the elements iodine and sulphur are first transported through the environment in the form of the gases methyl iodide and dimethyl sulphide and that both of these were the natural products of marine algae living at the ocean surface. I made this discovery during the voyage on a small ship from England to the Southern hemisphere and back. Everywhere the ship sailed these gases were found to be part of the ocean environment. Before the voyage scientists wrongly assumed sulphur and iodine to pass through the atmosphere as sea salt aerosol. Life they said plays no part in regulating the composition of the Earth, organisms merely turn over the chemicals that blind inorganic chemistry leaves for them to find.

The second discovery was that the long term climate of the Earth is regulated by the pump down of carbon dioxide in a controlled way by organisms living in the soil.

Slide 2. Geochemical rock weathering

There is only one source of the gas carbon dioxide: volcanos and volcanic processes, which bring it from the Earth's interior. There is only one long term sink for carbon dioxide: its removal from the air during the weathering of calcium silicate rocks. Geochemists had assumed that weathering was a purely inorganic process in which organisms played no part. With my colleagues Michael Whitfield and Andrew Watson, we proposed that weathering takes place at least thirty times faster when organisms are present. Our proposition was experimentally confirmed by the American scientists Schwartzman and Volk. It means that organisms control the abundance of atmospheric carbon dioxide and therefore the climate also. When it is cold soil organisms grow poorly and the pump down of carbon dioxide is slow, as a consequence carbon dioxide builds up in the air, and the world warms. When it is hot organisms grow fast and pump down carbon dioxide rapidly so as to cool the Earth. This is one process by which the Earth could have kept cool and comfortable in spite of a 25% increase in solar heat since life began. But there is a puzzle concerning the working of this pump in the present world. It is hotter now than it was in the ice age, but the carbon dioxide has increased, not decreased, or remained constant as would be expected if regulation were taking place. How could this be?

Before I answer let me tell you of the third discovery to come from Gaia because it is part of the explanation. The gas dimethyl sulphide has been found to do much more than merely carry sulphur from the ocean, where sulphur is abundant, to the land, where it is scarce and needed. Dimethyl sulphide oxidises in the air to produce a strong acid, methane sulphonic acid, MSA for short. This acid is known to be a major source of the nucleating particles on which cloud droplets form. Without the production of dimethyl sulphide by the organisms living in the oceans there would be fewer and less dense clouds and the Earth would be a hotter place. This work was done in collaboration with my colleagues Robert Charlson, Andi Andreae and Stephen Warren and reported in 1987. Again it was the Gaian view that motivated the search for a connection between the organisms living in the oceans and climate. We wondered if the algal production of dimethyl sulphide could be part of a Gaian feedback mechanism for keeping the Earth cool. As evidence accumulated it pointed not to regulation but the opposite, a tendency to destabilise climate.

The strongest evidence came from the chemical analysis of the ice cores taken in Antarctica. These showed clearly that as the Earth grew warmer following the last glaciation so the quantity of MSA laid down in the ice grew less. This means the warmer it becomes the fewer the clouds and the hotter the climate. Just like the carbon dioxide puzzle there is a positive feedback on warming, the opposite of climate self regulation in the Gaian way.

Slide 3 The ice core record of CO2 and MSA

I learnt early in my life as a scientist that evidence that appears to contradict a theory under test is more likely in the end to confirm it. The bad news for theory testers is neutral or uncertain evidence. The apparent contradiction can come simply from viewing the problem in the wrong way. In the present instance, if we consider the Earth system to be in a temporary state of failure then positive feedback is not unexpected. Consider the last time you had a fever. When a fever starts, the processes that normally cool, like sweating and the dilation of the blood vessels of the skin, cease to operate; we also produce more heat by shivering. These are all positive feedbacks characteristic of disease. Yet who would doubt that normally we regulate our body temperature very well.

If we look at the present Earth as a fevered system then the positive feedback between climate and carbon dioxide and between climate and clouds makes sense. But what is the justification for looking at the Earth this way? The first thing to note is that the Earth's climate for most of the present geological period, the pleistocene, has been cold. Only about one tenth of the time is spent in interglacials like now. Moreover the Antarctic ice records the deposition of seven times as much MSA in the glaciation as now; in addition, the carbon dioxide was less than 200 parts per million in the glacial state. Both facts imply a more abundant, or more vigorous, biosphere than we have now. Perhaps the system really does prefer it cool and the present interglacial, although comfortable for us, is a fever as far as the planet is concerned.

To test these ideas further my colleague Lee Kump and I have made numerical models based on Gaia theory. These models included plant life on the land surfaces to pump down carbon dioxide and algal growth in the ocean to generate cloud cover. We assumed that the optimum temperature for plant growth was 22 C and the optimum sea temperature for algal growth 12 C. This was not because algae have a different temperature preference to land organisms but because, for geophysical reasons, ocean temperatures above 12 C are associated with the formation of stable layers of warm water floating at the surface. These layers soon become depleted of nutrients and the algae cease to flourish. Our models predicted the self regulation of climate during the glacial cool state. The production of clouds by marine organisms and the pumping down of carbon dioxide both exerted a negative feedback on warming and kept a steady climate. The models also predicted the system to be close to the limit of stable operation and that even a small increase of solar heat could precipitate a change to a warmer and less stable climate. Before and after this change the system was in positive feedback.

A glance at a satellite view of the Earth taken to show plant growth on the land and algal growth in the oceans confirms that dense algal growth is limited to the ocean near the poles, and to upwelling water near the edge of continents, in both of these regions the temperature is below 12 C.

<u>Slide 4 View of Pacific to show limits of algal growth</u>

The land surfaces between 30 N and 30 S, where the temperature is above 22 for most of the year are either desert or tropical rain forest. We know that such forests are unstable and do not recover if removed; they are also ecosystems that are managing their own regional climate and would be likely to decline with increasing temperature. The models and the evidence are consistent with Gaian self regulation in the long term, but with a temporary failure in the present feverish world. The immediate cause of the change from glacial to interglacial was almost certainly one of the small regular changes in the Earth's inclination and orbital position with respect to the Sun, the Milankovich effect. By itself the increase in heat received is insufficient to cause the large change in climate from the ice age to the interglacial. The Milankovich effect was the trigger not the prime cause of the change.

If this planetary view of the present climate is correct it suggests that we have chosen a bad moment to add greenhouse gases to the air and to use so much of the natural ecosystems of the land surface for agriculture. More seriously the consequences of these acts could be amplified by the positive feedback of the system, and the climate of the coming century made hotter than is usually forecast.

<u>Slide 5 Model to illustrate the effects of global warming</u>

I started this lecture by praising journeys into space, and explained how they led to the re-discovery of Gaia. I realise that space exploration would not have happened when it did had it not been for the cold war between the superpowers; the enormous cost could only come from a military budget.

Space exploration was seen by politicians and scientists as an expression of their humanist creed. They saw it as a first step to dominion over the other planets. Their statements were full of hubris. Consider the vanity of the idea of terraforming Mars to make it a second home for people, when we are so far from knowing how to live with ourselves and with the Earth. Consider the absurd extravagance of space colonies. Bravado like this comes from those who see themselves as captains of star ships, in the quest to conquer space, always looking for the new frontier, but never noticing the mess they leave behind. I find such rhetoric in stark contrast to the words of the brave astronauts who made the journeys to the Moon. They saw the awesome immensity of space and how small is the Earth and realised poignantly that it really is home. I recall so well Jim Lovell, one of the three that nearly didn't return, telling me that even his thumb nail, held at arm's length, masked the Earth when seen from the distance of the Moon.

The exploration of space has also changed the balance of power between religion and science, and strengthened the authority of science in its claim to explain the mysteries of the Earth and the Universe. The superstitious and dogmatic side of religion lost much of its power over simple people when it became known that men had walked on the Moon. In 1969, when the first men landed on the moon, I was with my family in the far west of Ireland; in those days one of the most beautiful, least touched, and devoutly religious places in Europe. During the week that followed the landing people from the region called at our home and asked was it true that men had landed on the moon. I said yes did you not hear it on the radio? They replied yes but we needed to hear it from your lips to know that it was true. When I asked why, they said, "We need to know the truth. We want to know that there are no angels and heaven up there in the sky."

The true value of those journeys into space, whether real or in the mind, was the revelation of the Earth and the recognition it brought that the cult of humanism is not enough. The view from space teaches that we are part of a greater entity, the Earth, and that our survival and its good health are inextricably entwined. Perhaps in time we can expand our view to encompass the larger systems of the galaxy and the universe. Now the Earth needs our full attention.

I have tried to show the need for a planetary perspective, and a need to be to be sceptical about the claims of big science. The scientific community itself is divided and uncertain in the face of a world wide decline in funds. Scientists are human and for the most part concerned with careers, pensions, security and all the needs of modern city life. It is also not easy to be responsible where there is no accountability. This means that the science advisers, who may feel objective, are reflecting the needs and prejudices of the scientific community to which they belong.

A consequence is that the list of priorities often given by scientists reflects the list of working priorities of the scientific community, not the priorities of people, still less the priorities of the planet.

This is why until recently you would find global dangers listed in order of priority as follows: First, all things nuclear, whether power stations, processing sites, waste disposal or bombs. Second, ozone depletion. Third, the waste products of chemical industry. In other words, the first three priorities are things carcinogenic or mutagenic to humans, and things easy for scientists to measure. The greater danger from greenhouse gases, pollutants that threaten the planet, like carbon dioxide and methane, and the destruction of the forests of the humid tropics, are recent items on the agenda for action.

Through Gaia I see things very differently. To me the vast, urgent, and certain danger comes from the clearance of the tropical forests and from greenhouse gas accumulation.

The humid tropics are a habitat for humans and a physiologically significant ecosystem. We are destroying this habitat at a ruthless pace. Yet in the first world we try to justify the preservation of tropical forests on the feeble grounds that they are the home of rare species of plants and animals even of plants containing drugs that could cure cancer. They may do. They may even be slightly useful in removing carbon dioxide from the air. But they do much more than this. Through their capacity to evaporate vast volumes of water vapour, and of gases and particles that assist the formation of clouds, the forests serve to keep their region cool and moist by wearing a sunshade of white reflecting clouds and by bringing the rain that sustains them. It is easy to calculate the value of the tropical forests in terms of the energy that would be needed to provide the same air-conditioning and irrigation service. It is for the global tropical forests $500 trillion a year. Yet every year we burn away an area of forest equal to that of Britain and often replace it with crude cattle farms. Unlike farms here in the temperate regions such farms rapidly become a desert, more trees are felled and the awful process of burning away the skin of the Earth goes on. We do not seem to realise the damage we do. When we destroy more than a 70 to 80 per cent of a tropical forest the remainder can no longer sustain the climate and the whole ecosystem collapses. At the present rate of clearance it will not be long before the forests no longer have the critical mass they need to sustain themselves. When they vanish, the billion poor of those regions will be left without support. This is a threat greater in scale than a major nuclear war. Imagine the human suffering, the refugees, the guilt and the political consequences of such an event. It will happen at a time when we in the first world are battling with the surprises and disasters of the greenhouse effect intensified by the extra heating from the forest clearance. We could be in no position to help.

The population of the Earth first exceeded two billion in 1930. We have since then, at our present way of life, taken more from the Earth than it can supply in the long term. Once we passed five billion, the Earth could no longer support all of us even if we became wholly vegetarian and shared our food equally. As we are already 5.5 billion these calculations, taken from the World Hunger Project of the University of Rhode Island, are hardly cheering.

If we continue to place the good of mankind as the first item of our philosophical agenda and continue to ignore the Earth we shall see it pass through one of its major historical transitions. We, its first social intelligent species, will be privileged to be both the cause and the spectators. The transition imminent is a climate change at least as great as the change from the last ice age until now.

To give you some idea of the magnitude of the change ahead let us glance back to the depth of the last glaciation, some tens of thousands of years ago. Then the glaciers reached as far south as latitude 35 in North America and to the Alps in Europe. The sea level was more than 100 metres lower than now, and therefore an area of land as large as Africa was above water and covered with vegetation. The tropics were like the warm temperate regions are now. In all it was a pleasanter place to live on than now and there was more land.

To understand what is before us imagine a heat age, as much warmer than now as the ice age was cooler. Temperatures and sea level will climb, until eventually the world will be torrid, ice free, and all but unrecognisable. Eventually may be a long time ahead, it might never happen to that extent; what we have to prepare for now are the events of the transition itself, events that are just about to begin. These are likely to be surprises, things that even the most detailed of big science models do not predict. Think of the ozone hole, this was a real surprise. The most expensive computer modelling and monitoring of the Earth's ozone layer failed to see or predict it. It was seen by observer looking at the sky with simple instruments. Surprise may comes as climatic extremes, like storms of great ferocity, or as unexpected atmospheric events. Nature is non-linear and unpredictable and never more so than in a period of transition.

This is an occasion when we cannot look to Gaia for help. If the present interglacial warm period really is a planetary fever, we should expect that the system left to itself would be relaxing into its normal comfortable ice age. But such relaxation may be impossible because we have been busy removing the skin of the Earth for farm land, especially the trees and the forests of the humid tropics, which otherwise are among the means for recovery. We also are adding vast blanket of greenhouse gases to the already feverish patient. In these circumstances Gaia is much more likely to shudder and move over to a new stable state fit for a different and more amenable biota. It could be much hotter, but whatever it is, no longer the comfortable world we know. These predictions are not fictional doom scenarios, but uncomfortably close to certainty. We have already changed the atmosphere to an extent unprecedented in recent geological history. We seem to be driving our polluting civilization heedlessly down a slope into a sea that is rising to drown us.

These gloomy predictions will only come true if we do nothing to recognize that our planet is at least as important as ourselves. The future now depends on decisions made in this key part of the world where the supplies of energy and the development of technology go on most rapidly. We depend upon you here in the Eastern part of the Asian continent to discover how to use energy without harming the Earth and so without destroying ourselves. In this respect I see nuclear energy as less damaging to the Earth than the burning of fossil fuel.

I have spoken as an independent scientist. But I am far from being outside human concerns, I wish to see my grandchildren grow up in a world that has a future for them. Nevertheless, my detachment has thrust on me the vacant position of a Trades union representative. My members are all life other than humans, and includes the bacteria, the worms and the less attractive forms of life. I have to do this because there are so many who speak for people but so few who speak for them, on whom the planet depends more than it does on us.

From my laboratory in the English countryside I can see the stars at night and the milky way. In the day time I can hear the birds and smell the Earth.

To see, to feel the Earth this way, to think of it as a living organism turns our hearts and minds towards what should be our prime environmental concern, the care and protection of the Earth itself and especially of the forests of the humid tropics. It is not enough merely to be concerned for people. There is no tenure for anyone on this planet, not even a species. If we do not recognise our responsibility to our planet we may not even reach our allotted span. So let us be moderate in our ways and aim for a world that is healthy, beautiful and will remain fit for our grandchildren as well as those of our partners in Gaia.

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International co-operation for the safe and peaceful use of nuclear power

Hans Blix
Director General
International Atomic Energy Agency

Opening Session, Annual Conference of Japan Atomic Industrial Forum

Yokohama, 14 April 1993

Ladies and Gentlemen,

It is a great pleasure and honour for me again to address JAIF's Annual Conference. I should like to share with you some thoughts on two matters which are important to all of us and which are at the centre of the work of the IAEA, namely "international co-operation for the safe and peaceful use of nuclear power".

Our societies will not accept the use of nuclear power unless safety in the operation of reactors and in waste disposal is high. It is the responsibility of the nuclear community - scientists, engineers and regulators - to ensure this. Since safety must be ensured in all countries using nuclear power, international co-operation and international standards are indispensable. The International Atomic Energy Agency is the most important inter-governmental instrument for achieving this.

Our societies also ~~insist~~ demand that the expansion of nuclear power in the world ~~must~~ shall not be accompanied by a spread of nuclear weapons. They seek guarantees that ~~enriched~~ uranium and plutonium be internationally controlled and used only for peaceful purposes. In this respect, the IAEA has been given a crucial responsibility to operate the central control mechanism - the international safeguards system.

Both nuclear safety and nuclear non-proliferation present us today with a number of vital opportunities. They must be exploited to the full. Let me begin with safety.

SAFETY

It is strange that much of the public discussion of nuclear power continues as if nothing had happened to nuclear safety since the accident at Three Mile Island in 1979 and the disaster at Chernobyl in 1986. And yet we know that safety is continuously being improved and that these two events stimulated a host of new activities in the safety field: new conventions on early warning and emergency assistance, new measures for filtered containment venting, fire protection, training of personnel, etc. We know, moreover, that many of these measures are now being implemented on an international basis. It is true that risks can never be reduced to zero, but it is possible to demonstrate to the public the progress which has been made. The reduction in outages and in radiation doses to personnel and the increasing availability bear testimony to better maintenance, more reliable operation and safer nuclear power.

It can be noted with satisfaction that civil nuclear power operation in the past year was accident-free, but it was not - of course - incident-free. None of the incidents was of alarming proportions, but there were serious events - at an RBMK reactor at St. Petersburg in Russia, for instance. In my own country, Sweden, and in France some generic weaknesses were detected and remedied. There were also incidents in Germany and here in Japan at Fukushima. Although all of these incidents attracted a good deal of national and international attention, it should be stressed that the safety checks and safety systems functioned as they were meant to do. At the same time we are reminded that there is no room for relaxed vigilance.

In particular, the recent serious incident at a reprocessing plant at Tomsk in Russia is a reminder that sections of the nuclear industry which have not been subjected to the full rigour of public and international scrutiny remain potential areas of concern. Any inadequacies in military nuclear activities will have the same harmful effects on human health and the environment as inadequacies in civilian programmes. They will also have a damaging effect on perceptions of the safety of the nuclear industry as a whole.

INES

It is most important to be able to convey to the public an accurate idea of the severity of accidents or incidents - to that end we need a "Richter scale" for nuclear events. I am very pleased to tell you that introduction of the International Nuclear Event Scale (INES), an idea which was advanced at the IAEA and which was developed jointly by the NEA in Paris and the IAEA, has proved very helpful ~~for public information officers at nuclear plants and for the media~~ in informing the public ~~worldwide~~ in an understandable way about the relative severity of such nuclear events and thus to place them in their proper perspective. It is gratifying that forty-six countries - including Japan - are now co-operating in the use of the scale for nuclear power plants. The scale has moved out of its test phase into systematic, routine application, and its extension to nuclear facilities other than power plants is being considered. It would be unrealistic to think that the INES would eliminate the sensationalization of nuclear events, but at least a good tool now exists to characterize the gravity of events - provided, of course, that the will to do so is there.

Safety Services

Another encouraging development is that the various safety-related expert advisory services which are offered by the IAEA - known by their acronyms like OSART (Operational Safety Review Team), ASSET (Assessment of Safety Significant Events Team) and RAPAT (Radiation Advisory Protection Team) missions - are being increasingly requested by plant operators and Member States in order to bolster their own national efforts. Although these missions are sent only upon express request by individual countries, they may be expected to contribute to high safety standards internationally, because they represent the state of the art and because practically all States ask for them. This year Operational Safety Review Teams (OSARTs) and ASSETs will be going to France, Slovenia, the Republic of Korea, Argentina, Slovakia, Romania, China, South Africa, Bulgaria, the Netherlands, Lithuania, Ukraine, Russia and the Czech Republic.

Nuclear Safety Convention

Safety services have the effect of contributing in a very concrete and practical way to respect for internationally recognized standards, but their use of them implies no automatic commitment by governments to specific nuclear safety norms. It ~~has become apparent~~ is widely felt that the time may be ripe to work out a Nuclear Safety Convention. ~~in which a number of undertakings on fundamental safety norms and their implementation are laid down.~~ By adhering to such a convention States ~~would~~ will demonstrate their commitment to an international nuclear safety standard. At the same time the Convention would demonstrate to the public that there are international safety norms that have virtually global acceptance. There is no question of replacing national regulations and national responsibilities and prerogatives, but rather of complementing these at the international level and contributing to international transparency. The scope, contents and nature of such a convention have been discussed among governments for some time. The norms to be laid down must not be so general that they fail to offer specific guidance or set specific standards, nor must they be so detailed that they become a straitjacket. Much will depend on the arrangements which are made in the Convention for implementation, for instance through peer review of the parties. These arrangements might permit procedures for dialogue and persuasion.

So far there is only a consensus that the Convention should cover power reactors. If the Convention now being discussed were, in fact, to be limited to power reactors, it seems evident that subsequently other nuclear installations and activities should be similarly covered - notably waste disposal.

Nuclear Safety in East and Central Europe

One region of the world continues to give rise to special concern from the viewpoint of nuclear safety.

States in Eastern and Central Europe and some of those that formerly belonged to the Soviet Union are wrestling with a four-fold problem: how to meet current domestic energy needs; how to ensure in that context that their existing nuclear power plants function safely; what to do about completion of unfinished plants, of which there are about 20; and how to plan and finance their future energy sector, including the nuclear component. All of this against a background of severe economic and other strains.

The dependence of most countries in this region on nuclear generated electricity is high; ~~50% in Hungary (where the VVER-213s have been running well), 45% in Lithuania;~~

~~35% in Bulgaria, 28% in the former Czechoslovakia. The Russian figure of 12% is an average, I should note.~~ Some areas of Russia are almost totally dependent on nuclear power! It is clear that nuclear power is and will remain a substantial provider of electricity throughout this vast region. ~~The Russian Government recently endorsed an ambitious plan which foresees building or completing as many as 30 nuclear power stations over the next 20 years.~~ At the same time it is evident that acceptance of nuclear power in Russia, as elsewhere in the world, will be dependent on the safe and reliable performance of existing reactors and the public's regaining of a confidence that was severely shaken by the Chernobyl accident.

Existing Soviet-designed reactors ~~suffer from~~ have a variety of shortcomings, in some cases relating to design and operation, in others stemming from the quality of manufacture and construction. In some rare instances, as in Armenia, decisions have been taken to close an operating unit. However, in view of energy shortages, we can expect that the remainder - I am talking about some 60 units - will in all likelihood continue to run, the oldest and most problematic for a limited number of years, others for a longer time.

There is naturally a strong interest all around the world that the safety in these plants be strengthened without delay. The Chernobyl disaster led to a moratorium on new nuclear power construction in a great number of countries and any new severe accident would reduce prospects for a nuclear revival. This concern is a natural basis for substantial assistance to back the efforts which the Russian and other governments in East and Central Europe are making. The pressing need for comprehensive safety assessments, upgraded safety systems, improved operational safety and strengthened regulatory oversight has been recognized for several years. The IAEA helped at an early stage with the safety assessment of the 440/230 VVER reactors in Bulgaria and the World Association of Nuclear Operators (WANO) has been giving practical help in that country. There have been valuable bilateral or joint initiatives elsewhere, notably through the Group of 24, we must regret that the organization and preparation of assistance has been far too slow. In my view it would have been to the advantage of both donors and recipients if more use had been made of the IAEA, which has a long experience in nuclear co-operation with East and Central Europe.

At present it seems there will be a blend of bilateral and multilateral projects. ~~The~~ European Bank for Reconstruction and Development in London ~~has been given a green light to start active involvement as a multilateral aid channel, with "seed-money" pledges coming in from the G-7 and~~ G-24. ~~Also,~~ the European Investment Bank in Luxembourg ~~is becoming involved with sizeable amounts in loans said to be available. Last but not least the World Bank in Washington is currently elaborating future energy strategy options for the region~~.

It is gratifying that these initiatives are gathering momentum, for it is high time to move from the stage of the innumerable technical visits and studies to implementation of practical improvements at the plants. The necessary sense of political will and urgency needs to be maintained so that the work can be given new impetus through the next G-7 summit meeting here in Japan in July.

I can assure you that the IAEA is trying both by working with other organizations like the G-24, and through its own programme to assist in the efforts which are now underway. Thanks to financial support, notably from the Japanese Government, the IAEA has been able to carry through in-depth safety analyses of the early generation Soviet-designed PWRs - the VVER 440-230s. It is our intention to extend our analytical work to cover the later model PWRs - the VVER 440-213s and the 1000s - and the RBMKs. Our essential task is to diagnose shortcomings and assess improvements which have been undertaken. We can mobilize impartial and competent experts to do this. Decisions regarding remedies involve political and commercial judgement and are essentially for the States concerned. By now the IAEA has carried out safety-related review missions of one type or another at most reactor sites in Eastern Europe. These missions have included operational reviews and assessments of operational events as well as design reviews in some cases. Within the resources made available by Member governments - and shortly through collaboration with the UN Development Programme (UNDP) - the IAEA is thus contributing to the current efforts to assist East European countries in the strengthening of nuclear safety.

In concluding my remarks on the question of nuclear safety in East and Central Europe, let me say that due to the centralized organization of the USSR many of the ex-Soviet States need assistance to build up their own nuclear safety and radiation protection organizations. As to the power reactors, let us not overlook that nobody knows them better than the people who have designed them and have been working with them for years. They need assistance to overcome the relative isolation in which they have worked; they need some sophisticated and high quality equipment; they need constructive outside comments and assessment - but they don't need any patronizing attitudes. On the other hand, nuclear safety cannot be limited to the operation of nuclear power plants. The hazards involved in the operation of other facilities in the nuclear fuel cycle, including reprocessing plants and waste treatment centres must be assessed and taken into account. In the former USSR most of those facilities were operated in restricted areas under military authority. The present openness and transparency of the Russian Federation should help to increase co-operation with the IAEA in these areas.

Ensuring Exclusively Peaceful Use

I turn now to the second aspect of my remarks, that of ensuring the exclusively peaceful use of nuclear power.

Controlled nuclear energy was born in war. So long as nuclear weapons remain stored anywhere there remains a risk that the mushroom cloud will be seen again. Even when the number of nuclear weapons is rapidly decreasing, as it will do in the years ahead, there is a risk of further countries acquiring such weapons. As inhabitants of this world and as protagonists of the peaceful uses of nuclear power we have a strong interest in nuclear disarmament and non-proliferation. Nuclear power may owe its birth to the development of nuclear weapons, but the~~ir~~ continued existence of these weapons is a handicap for nuclear power.

Four recent developments have focussed interest ~~in the last few years~~ on the need to co-operate in preventing the spread of nuclear technology for military purposes. First, the discovery of how close Iraq came to success in secretly developing a nuclear military capability; second, the ending of the Cold War, which gives hopes for a world in which peace is no longer dependent upon a balance of terror but in which the dissolution of the former Soviet Union is also raising some fears about the trickling out of nuclear material and know-how; third, the recent events in North Korea; lastly, interest and debate have been triggered by the growing quantities of plutonium, whether separated in the peaceful cycle or recovered through the dismantlement of nuclear weapons.

Before dealing with each of these problems, let me first stress that there is a good deal of positive news. The conclusion by Russia and the United States in early January of the START-2 Treaty was a major achievement, foreshadowing deep cuts in strategic arsenals on both sides. ~~Problems remain before we can hope to see this Treaty implemented, but the~~

~~achievement of agreement, and in record time, is in itself remarkable~~. Everything should be done ~~in the months ahead~~ to help ensure ratification and implementation, including financial and technical help needed for the dismantling and recovering of fissile materials from deactivated strategic weapons. I know Japan is among the countries looking closely at this question.

There has also been a welcome moratorium in nuclear weapon testing that will last at least until this summer and possibly beyond. We must certainly hope that agreement will soon be possible on a date for a complete halt to nuclear weapon tests. Agreement might also be achievable on a cut-off in the production for weapons purposes of enriched uranium and plutonium. These two kinds of agreement would be strong and encouraging signals as we approach the Non-Proliferation Treaty Review Conference due in 1995, at which a decision has to be made on extending the duration of the Treaty. One of the persistent criticisms of the Treaty in the past has been that the nuclear "have-nots" have ~~stood behind~~ carried out their substantive commitments, while States possessing nuclear weapons have only given general promises about disarmament measures. If these promises turn into specific action, as we can now hope, support for the NPT will be without reservations. There will be a feeling that all countries are genuinely doing their part to bring us toward nuclear-weapon-free world.

The NPT, which has been in force since 1970, remains the cornerstone of international efforts to inhibit the spread of nuclear weapons. That the Treaty is a living instrument is shown by the fact that there were more new signatories last year than in any single year since 1975 - a total of nine States. Not only did China and France, the last two declared weapon States, come in, but so did Estonia, Slovenia, Uzbekistan, Azerbaijan, Namibia, Niger and Myanmar. There are now 155 NPT States parties in all.

There are reasons to expect that Ukraine and Kazakhstan will follow suit in due course. They have declared their intention to do so. From the Agency we have already sent technical briefing and fact-finding missions, to over 30 major installations to prepare for safeguards operation in these countries. Other teams will go to Latvia, Armenia and Georgia. Once such countries have signed the NPT, safeguards agreements can follow between each of them and the IAEA. We are already helping those States that do not have great depth of knowledge in the nuclear accountancy or physical protection spheres to enhance their capabilities. Some individual States such as Sweden, Finland, Hungary and the United Kingdom have been doing the same. The idea is to get off to a "flying start" once formal safeguards agreements are ready for signature and implementation.

The emergence of a series of independent nations joining the NPT and accepting safeguards as non-nuclear-weapon States, and new safeguards tasks verification being called for in South Africa, in the Democratic People's Republic of Korea, and in Argentina and Brazil, will certainly expand the areas in the world in which it is verified that nuclear energy is used exclusively for peaceful purposes. The work laid upon the Agency will increase. I only fear that the Agency will be left to do this with the same financial and manpower resources as hitherto. I cannot help wondering at times whether it is wise for the international community to dress the safeguards effort in the zero real growth straitjacket, leaving some 60 million dollars a year for the safeguards operations? If it were not for the fact that some IAEA manpower resources will soon be freed up for redeployment to these new tasks through a revised work-sharing arrangement with the Euratom reducing our inspection burden in the European Community, we would simply not be able to cope with new burdens. If the international community will require more - and more effective - verification of nuclear activities, the necessary resources for it must be made available.

I turn now to the lessons of Iraq, and I shall highlight a number of important practical actions that have been taken within the IAEA itself to strengthen the safeguards system. The case of Iraq raised the question whether the welcome increase in the number of parties to the NPT is matched by an unwelcome erosion in the respect for the obligations assumed under the Treaty. Are there more Iraqs? What is done to strengthen the safeguards system to reduce the risk that a secret programme may go undetected?

Even though there were suspicions before the Gulf War about a clandestine enrichment programme in Iraq, the secret facilities were apparently not identified by satellites, intelligence - or IAEA safeguards. In the IAEA we have asked ourselves what measures would have increased the chances of discovering such a programme - and we have introduced such measures.

The first and most fundamental is information. If a State does not declare what it is doing in the nuclear sphere - and secret programmes are by definition not declared - knowledge about the activity must come from somewhere else.

To strengthen the information basis of the safeguards system all Member States are now asked to provide the Agency - on a voluntary basis - with information relating to the export and import of nuclear materials, specified equipment and certain relevant non-nuclear related materials. If we had had such information regarding Iraq we might well have detected the emergence of an unusual pattern of procurement in a timely fashion.

In general there appears to be acceptance of this reporting scheme, and we are now establishing a data base to process the information received. The submission of the information will be voluntary, as I said, but the hope is that it will achieve universality in due course. If this comes about, then it will strengthen and complement the IAEA safeguards inspection and verification regime to a substantial degree.

In another significant development, the Agency has begun to receive some information from third party sources regarding possible evidence of non-declared materials, activities or facilities in other States having comprehensive safeguards agreements, typically but not always as NPT parties. I should mention that the Agency's inspectors did not have access to such evidence prior to the Gulf War. And that it was such evidence that led many of the Security Council mandated inspections to the right places in Iraq after the war. Inspectors must have access to good and reliable information in order to know where to probe.

Some ask, is it appropriate for the Agency to make use of information obtained through satellites or national intelligence? My answer is that all information that appears to be safeguards relevant must be received and analysed. The Agency is supposed to be a watchdog - not an ostrich! However, there is much erroneous information around and much disinformation. All information must therefore be critically assessed and analysed.

If it appears, after evaluation of information received, that there are questions to ask, clarifications can be sought from the State concerned. Should these be withheld or be unsatisfactory, a special inspection can be requested to undeclared sites, even over the objection of the State.

If information is crucial in order to know where to go, the right to unimpeded access for inspectors to any sites which appear nuclear-safeguards relevant is the necessary means to use such information. The Agency's right under standard safeguards agreements to call for special inspections has recently been reaffirmed by its Board of Governors in the case of the Democratic People's Republic of Korea. If such inspections are declined as they were in ~~the~~ this case ~~of the DPRK,~~ the matter may be referred to the Security Council.

I should mention one more new feature, namely the invitations which have been extended to the Agency by some States to visit any site or installation, regardless of whether it has been declared and regardless of whether the Agency has reason to believe that the site contains something that should have been declared but was not.

Such invitations have so far been offered by Iran, Libya, South Africa and the DPRK. ~~Such~~ Visits of this kind ~~visits~~ have some advantages: they provide a general ~~transparency~~ openness and they may enable the Agency to ~~ask to see something~~ visit sites even when available information may be too vague or uncertain to justify a request for a special inspection. Such invitations may also enable a country to clear itself of any allegation that a particular site or installation is clandestine and should have been declared. Of course the contribution to transparency and confidence of such offers depends on the willingness of States to adhere to them in practice. ~~In the case of the DPRK the refusal to permit visits has only heightened concerns.~~

I should mention, lastly, among the measures to give the safeguards system sharper teeth, that new analytical techniques give the Agency and its laboratories powerful means through which much can be learnt even from small particles taken from inspected installations.

It is important to remember nevertheless that the NPT and Agency safeguards, while central, are only part of the total non-proliferation "architecture" designed to prevent the further spread of nuclear weapons and comprising a number of barriers and incentives. Where the political barriers may not suffice to discourage a State from the weapons path, greater restraint on exports on the part of supplier States may make nuclear weapon development more difficult. Such sharpening of the export controls has been agreed to among major exporters.

~~A major problem encountered by~~ IAEA safeguards ~~inspections has of course occurred~~ in the Democratic People's Republic of Korea - North Korea. After a number of inspection missions there, and analysis of many samples and records, significant differences remain between the Agency's findings and the information given by the DPRK. As a result the IAEA cannot confirm the correctness of the DPRK's initial report ~~as to the amounts of nuclear material~~ the country has ~~notably plutonium~~. We have not obtained the necessary clarifications through our inspections and discussions, nor been ~~given access~~ to take samples from two apparently nuclear-waste-related undeclared sites at Yongbyon, [illegible] we have requested access to additional information and to these sites under the rules relating to [illegible] special inspection ~~in our safeguards agreement with the DPRK~~. Although [illegible] endorsed by the Board of Governors of the IAEA, this request has not been ~~acceded~~ ~~to~~ ~~so far and the~~ matter has been submitted to the Security Council, which is also considering the DPRK's intention announced ~~on March 12~~ to withdraw from the Non-Proliferation Treaty. It is evident that the obstacles to effective safeguards verification in the DPRK raise security concerns ~~for all~~ countries in the Far East. Only [illegible] return to full nuclear transparency with unimpeded access for inspections and sample taking will restore confidence.

[illegible]t I have described to you [illegible] a picture of problems and possibilities. The problems ~~must be tackled, to be sure, but~~ the prospect of a nuclear-weapon-free world is no longer Utopian, ~~even though it may still be rather far away~~. In the present situation it is not unreasonable in my view to aim at an unlimited extension of the Non-Proliferation Treaty when it comes up for review and prolongation in 1995, and also at universal adherence to non-proliferation commitments. Such adherence need not consist in accession to the NPT itself but could be achieved in the context of a regional nuclear-free zone type arrangement, as we have seen in the case of Argentina and Brazil. In such a framework, bilateral and multilateral inspections could play a mutually reinforcing role. This is the kind of scenario one could envisage in the context of a Middle East peace settlement. The Indian subcontinent - which I have just visited - would probably also require a tailor-made formula, but progress there presupposes both regional detente and further steps towards global disarmament.

I want finally to touch on the question of plutonium. The quantities of separated plutonium and plutonium contained in spent nuclear fuels are growing in the civilian nuclear sector. So are the quantities of plutonium which we expect to be recovered through dismantling nuclear weapons. All this plutonium must be stored, transported and used in a manner that is fully reassuring from a viewpoint of safety and non-proliferation. While each country decides how to address these issues, there are international aspects as well.

~~In recent years the IAEA Secretariat has been requested to provide Member States with data on the production of plutonium. That information has been made available and periodically updated.~~ The Agency ~~also~~ applies safeguards to plutonium in accordance with relevant agreements. There is a question whether additional safety and safeguards guarantees could be provided by a stronger involvement of the IAEA ~~in this context~~. We have held one exploratory meeting at which *inter alia* the idea of international plutonium storage was reviewed.

Certainly, if additional assurances concerning non-diversion and exclusively safe and peaceful use of plutonium are desired, then arrangements would be called for under which the growing quantities of plutonium would be subject to special controls. The Statute of the IAEA envisages a function of this kind for the organization and the dialogue that has recently been re-opened will be continued.

The post-cold-war political climate creates favourable conditions for disarmament and non-proliferation. We can look forward to a future in which international co-operation is freed from many of the ideological hindrances of the past. It can be applied to both the need for nuclear safety and nuclear non-proliferation and it will help us to maximize the benefits of nuclear power as a major environmentally-friendly and readily available source of energy.

NUCLEAR IN THE UNITED STATES: THE CHALLENGE OF CHANGE

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There are many challenges facing the nuclear arena in the United States today, challenges emerging from an everchanging environment. This paper focuses on several significant changes in the United States that may affect the development of nuclear energy as well as several significant international challenges that the United States, and indeed, the entire international nuclear community, must address if the peaceful uses of nuclear energy and nuclear materials are to be available for the benefit of humankind and the environment in the future.

Changes in the United States

The Energy Policy Act of 1992

In the United States, there have been many changes in the past few years, creating challenges for society as a whole as well as for the nuclear community. Among these changes was the enactment of the Energy Policy Act in October 1992 which for the first time codifies a national energy strategy for the United States. This statute affects such major nuclear issues as plant licensing, advanced reactors, uranium enrichment, and high-level radioactive waste.

In the area of plant licensing, the Energy Act of 1992 essentially codified the Nuclear Regulatory Commission's (NRC) program to certify standardized plant designs as well as NRC's new "one-step" licensing process. Design certification completes review of a standardized plant design before construction, thereby resolving safety issues up front. Design certification also defines the inspection, test and analyses acceptance criteria (ITAAC) that will be used to demonstrate that a plant is built and will operate in accordance with the design certification. The licensing process also permits a potential applicant to perform an early site permit review. A utility may then file an application for a license to build and operate a reactor whose design has been certified on a site that has received a permit. This "one-step" approach i.e., processing a license to both build and operate, streamlines licensing and reduces regulatory uncertainty. It is expected that all future standardized design applications, site permits, and construction/operating license applications will be processed in accordance with the revisions of the Energy Policy Act.

Although not addressed in the Energy Policy Act, another licensing issue that the NRC is working on is license renewal which in the United States is required if a plant is to operate beyond the 40 year period of its initial license. The NRC issued a final rule in December 1991 stating that a nuclear power plant's license can be renewed if measures have been taken to deal with age-related degradation so that the plant continues to meet the standards of *its current license. The Commission has had several briefings on licensing renewal by the staff as well as the Nuclear Management and Resources Council (NUMARC). The NRC staff is currently working on the processes for implementing the rule, the key challenges being how to define the systems and components subject to age-related degradation unique to license renewal and how to utilize the Maintenance Rule in this regard.*

The Energy Policy Act has also changed how the United States manages uranium enrichment and operation of the gaseous diffusion plants. The Act transfers this responsibility from the United States Department of Energy (DOE) to the newly established United States Enrichment Corporation. It requires both that NRC develop standards for these plants by October 1994, and that NRC act as the regulator of the operations of the facilities (in consultation with the United States Environmental Protection Agency), through periodically certifying whether the plants meet the standards. In addition to needing to resolve an ambiguity as to when NRC's oversight responsibilities commence, the NRC must determine exactly what is required for "certification." Since these facilities have been operating for many years, the NRC will essentially need to develop standards for operating facilities as opposed to following the traditional approach of approving a license and at the same time establishing an inspection regime for the new facility.

With respect to high-level waste, the Energy Policy Act calls for the United States National Academy of Sciences to provide recommendations and findings concerning standards for protection of the public from radiation releases from the high-level waste repository planned at Yucca Mountain. These recommendations are due to the United States Environmental Protection Agency (EPA) on December 31, 1993. The Act then requires the EPA to promulgate regulations consistent with the recommendations within one year, at which time the NRC will have another year to reconcile its regulations with the new EPA regulations.

Until a repository is available, high-level waste must be managed. In December 1992, then Secretary Watkins announced that the DOE would not be able to receive spent fuel by 1998 as required by law at either a monitored retrievable storage facility or the proposed repository at Yucca Mountain and that interim storage at federal facilities would be pursued for this purpose. Many individual reactor licensees have built dry storage facilities at their sites for spent fuel until the DOE is prepared to accept it. For such onsite storage, the NRC has licensed several cask designs. A concept currently being advanced is that of a "universal cask." A universal cask would be capable of use in storage facilities as well as for transportation to a repository. This would reduce the handling of the fuel assemblies and thus minimize personnel exposure. The NRC is examining whether any regulatory changes are needed for approval of this concept.

The New Administration

Although considerable change has been brought about by the Energy Policy Act of 1992, many would argue that the change in administrations from George Bush to Bill Clinton will have an even greater impact. A hint of possible changes came when President Clinton delivered his first address to Congress on February 17, 1993 which included several items affecting the energy arena.

In this address, President Clinton proposed a new energy consumption tax. As proposed, all fuels, except wind, solar, and geothermal power, would be taxed according to their energy content as measured in British Thermal Units (BTUs). The tax is intended to generate revenue, create an incentive for energy conservation, help stop environmental damage and reduce greenhouse gas emissions by the turn of the century, and improve United States competitiveness and the balance of trade. There is still some uncertainty, however, regarding exactly where the proposed BTU tax would be collected i.e., point of generation or consumption, and whether or not the proposed tax will ultimately be approved by Congress.

President Clinton also stated during his address that "We're eliminating programs that are no longer needed, such as nuclear power research and development." The administration's general budget plan calls for continued funding of nuclear research and development only to maintain the current generation of reactors and *the "licensing actions for reactors that have commercial interest." At this time, this is expected to phase out advanced reactor programs such as the PRISM reactor and the Modular Gas-Cooled reactor but continue the Matching Fund Program for first-of-a-kind engineering.*

It is not yet clear how the proposed cuts will be reconciled with the Energy Policy Act. The Energy Policy Act directs that a comprehensive program be carried out by the Department of Energy to encourage the development of advanced nuclear reactors eventually leading to their commercialization after September 1996. At this point, it is still too soon to tell how these proposals will materialize and how the new administration will actually shape nuclear energy policy.

In the meantime, at the NRC the review of reactor designs, both evolutionary (General Electric Advanced BWR and Asea Brown Boveri/Combustion Engineering System +80) and passive (Westinghouse AP-600 and General Electric Simplified BWR) is continuing. The staff is working to resolve technical issues on the individual designs and to further define the rulemaking process from Final Design Approval through a Design Certification rule.

<u>Low-Level Waste Storage and Disposal</u>

Low-level waste disposal continues to be a complex and difficult issue for the United States.

The Low-Level Radioactive Waste Policy Amendments Act of 1985 provided for the establishment and operation of regional disposal facilities by "compacts" (a contractual and legal affiliation of states). Progress by the compacts has been glacial at best and generated some challenging regulatory debates centering on issues of states' rights, especially regarding whether or not states have the right to set more stringent radiation protection standards than the federal government.

Low-level waste disposal is rapidly becoming a very critical issue affecting not only operating plants but materials licensees, such as research and medical facilities as well. Since January 1, 1993, only one low-level waste facility is accepting non-compact-state material; fees have risen and can be expected to continue to rise dramatically. After June 1994, this facility will only accept waste from within its compact. Unless other facilities are sited and established by that time, only 13 of the 50 states will have access to a disposal facility.

A recent Supreme Court decision has also affected the low-level waste disposal situation. In June 1992, the court ruled unconstitutional the "Take Title Provision" of the 1985 Low-Level Radioactive Waste Policy Amendments Act obligating states to take legal title to, and possession of, low-level waste from generators within their jurisdiction or be liable for all damages if disposal facilities were not provided by either the state or a compact on

January 1, 1996. The potential impact of this high court ruling on low-level waste management and thus on the nuclear community is still unclear.

Challenges in the International Community

While the United States is facing the challenge of change domestically, the global situation continues to evolve, impacting the United States along with the rest of the international nuclear community. International challenges include efforts to establish nuclear reactor safety standards, increase the level of nuclear materials safety, reduce radiation exposure, safeguard nuclear materials and facilities, and build nuclear waste storage and disposal facilities, all aimed at protecting the public and environment from any harmful effects of radiation.

The ability of the international community to collectively meet each of these challenges and address related changes as they develop will determine if nuclear power is to survive and continue to be a viable source of energy for all countries.

Nuclear Reactor Safety Standards

Certainly critical is the ability to establish a reasonable level of nuclear reactor safety standards and a safety culture around the world. For its part, the NRC has signed agreements for cooperation with 27 countries to assist with technical research, develop *regulations, and prepare technical guidance. An example is NRC's work with the United Kingdom's Nuclear Installations Inspectorate on the licensing of England's first pressurized water reactor, the Sizewell-B nuclear power plant. Additionally, the United States is working with Japan on containment structures research, testing thermohydraulic safety conditions for the Westinghouse AP-600 advanced reactor, and the development of hydrogen ignition criteria.*

In 1988, the NRC signed a significant bilateral agreement with the Soviet Union establishing the Joint Coordinating Committee for Civilian Nuclear Reactor Safety (JCCCNRS). The Committee is responsible for directing technical cooperation through working groups assigned specific topics, such as embrittlement, reactor vessel annealing techniques, fire safety, health effects, and nuclear power plant aging and life extension. While there have been many significant changes since the signing, the agreement is continuing to be carried out with countries of the former Soviet Union.

In the last few years, there has been considerable support from many countries and international organizations to address the safety problems of nuclear power reactors in the former Soviet Union and Eastern European countries. This includes efforts through the G-24 Coordination Center for Nuclear Safety Assistance, the Lisbon Initiative, the G-7 process, and preliminary efforts to establish a multilateral fund.

International organizations clearly play a very important role in establishing and maintaining strong nuclear reactor safety standards. The United States has multilateral agreements with the International Atomic Energy Agency (IAEA) and the Organisation for Economic Cooperation and Development's (OECD) Nuclear Energy Agency. With the IAEA for example, the NRC has assisted with the development of international safety fundamentals and has been extensively involved in negotiations supporting the establishment of the International Nuclear Safety Convention. The United States believes it is vital for the international community to continue its work with these organizations and support their efforts.

Nuclear Materials Safety

The United States has become increasingly concerned about nuclear materials safety, particularly regarding the proper disposal of unwanted sealed radioactive sources. Such sources have been discarded and become mixed with metal scrap that is later recycled. This has led to inadvertent smeltings of radioactive sources by mills and foundries. In the United States the first reported accidental smelting of a radioactive source occurred at a steel mill in New York in 1984 and involved a 25 Ci cobalt 60 source. There have been a total of 15 accidental smeltings reported in the United States. Additional accidental smeltings are known to have occurred elsewhere in the world. In some of these cases contaminated metal products were exported to other countries. In the United States damage from accidental smeltings has been largely limited to contamination of the mill environs and products. Fortunately, plant worker and public exposures have been minimal. Costs for decontamination and disposal of contaminated wastes, however, can be significant. Decontamination and waste disposal costs have gone as high as 5 million dollars. Elsewhere in the world significant public and worker exposures to radiation have resulted from sealed sources entering the metal scrap cycle, notably in 1984-85 in Mexico when a 400 Ci teletherapy unit was dismantled and sold as scrap and in Brazil in 1987 when a 1375 Ci cesium-137 teletherapy unit was dismantled, again for its scrap value.

The United States is actively promoting international symposia, working to establish internationally accepted guidelines, assisting countries where accidents have occurred, and assisting the IAEA in establishing a radioisotope training course for foreign personnel at the Argonne National Laboratory. United States personnel continue to serve as lecturers, provide training materials, and serve as technical members of IAEA Radiation Protection Advisory Teams (RAPAT).

The importance of this issue cannot be emphasized too strongly, because problems continue to occur in many countries causing *serious or fatal radiation exposures. This poses a very difficult challenge to the world community as commerce and trade in commodities that lend themselves to such problems increases.*

Radiation Protection

Considerable changes have occurred internationally regarding radiation protection, and the United States is in a position to learn much in this area from other countries. For example, occupational doses in nuclear power plants appear to be higher in the United States than in some other countries. By reviewing the radiation protection programs of these countries, the NRC is trying to determine what changes can be made to improve the situation in the United States. The NRC is just beginning to implement the radiation protection requirements of ICRP 26 and, along with many nations, will study carefully those who are already moving ahead to consider the requirements of ICRP 60.

Of key importance to all is the sharing of new information on health effects and environmental protection. To address the health effects from the Chernobyl accident specifically, the United States established a technical working group under the auspices of the JCCCNRS. But this must be regarded as only a small effort, and the United States looks forward, with the rest of the world, to a thorough and clear understanding of the effects of this accident on the health of workers and the public as well as the environment.

In addition, studies of both workers and the general public associated with weapons facilities over the past several decades, especially in the United States and in Russia, are desirable to expand and clarify the body of knowledge on health effects. The availability of medical, dosimetry, and environmental data associated with these sites presents a unique opportunity to expand our knowledge of radiation health effects. But efforts to tap this information should proceed expeditiously, lest the opportunity be lost.

Safeguards and Physical Protection

In the realm of physical protection of nuclear materials and nuclear non-proliferation, of great importance to the United States and significance to the world are the issues surrounding the extension of the Nuclear Non-Proliferation Treaty (NPT) after 1995. The United States continues to support an indefinite, unconditional extension of the NPT in the interest of fostering international peace and security.

To strengthen safeguards efforts world-wide, the NRC has periodic meetings with representatives of other countries, and participates in bilateral information exchanges and international conferences to discuss national physical protection programs. The United States is one of many NPT countries represented at the international Non-Proliferation Treaty Nuclear Exporters' Committee (Zangger Committee) meetings to discuss nuclear-related export issues.

In support of United States non-proliferation and safeguard objectives, the NRC has been carrying on a program of technical cooperation with Russia and Ukraine to establish a physical protection system for nuclear materials control and accountability similar to that in the United States. In addition to system design, activities include assistance in drafting regulations and guidance documents.

In February 1993, the United States signed an agreement with Russia to purchase low enriched uranium converted from highly enriched uranium at facilities in the Russian Federation. The United States believes that implementation of this agreement will reduce Soviet stockpiles and provide hard currency to address safety problems in Soviet nuclear reactors. The uranium is expected to be used as fuel for use in commercial reactors.

Nuclear Waste Storage and Disposal

A final area of concern to the entire nuclear community is the storage and disposal of nuclear waste as well as public opinion on this issue. Each country clearly has its own problems and solutions for managing high-level and low-level waste. However, a great deal of information and experience concerning waste storage and disposal can and should be shared among countries.

Many countries are making progress in the management of nuclear waste. These countries often have 2 things in common that deserve attention: their focus on performance-based standards, and their time intervals of consideration. These countries are emphasizing the ability to retrieve waste in the future as technology improvements or resource requirements dictate. As indicated earlier, the course that the United States will ultimately pursue is not yet fully defined.

Countries must not only work to provide appropriate standards, they must work diligently to inform the public of why and how the standards were developed. As many countries know, without public support, the issue of nuclear waste storage and disposal has the potential to severely hinder the future of nuclear energy. Winning positive change in public perception certainly is an important challenge to all.

Conclusion

The nuclear community of today is a small world and countries must work together to meet the challenges before us, the challenges of an everchanging environment. While the United States faces the changes brought by the Energy Policy Act and the new administration, the global situation continues to evolve, impacting the United States along with the rest of the international nuclear community. International challenges include those arising from the effects of the political changes in the former Soviet Union and Eastern Europe, the effort to establish internationally accepted *levels of safety through an International Nuclear Safety Convention, the effort to ensure adequate and effective safety and safeguards programs through the International Atomic Energy Agency and its member states, and the issues facing all nations regarding nuclear waste.*

While change may bring challenge, from challenge often springs strength and commitment. The key is to recognize the challenge of change. In 1881, John Viscount Morley noted

> *Great economic and social forces flow with a tidal sweep over communities that are only half conscious of that which is befalling them. Wise statesmen are those who foresee what time is thus bringing, and endeavor to shape institutions and to mold men's thought and purpose in accordance with the change that is silently surrounding them. ("Life of Richard Cobden")*

May we in the global nuclear community be wise statesmen. May we recognize the change, rise to the challenge, and work together to ensure that the peaceful uses of nuclear energy and nuclear materials are available for the benefit of humankind and the environment in the future.

Viktor N. Mikhailov
Minister for Atomic Energy of
the Russian Federation

"NUCLEAR POWER IN RUSSIA TODAY AND TOMORROW"

After several years of uncertainties as to the future of nuclear power in Russia, evoked by the Chernobyl accident and transformation of the political & economical system in the country, some very specific trends of its further development have been already defined by the current moment. These objective trends are being stipulated by the existing economical and ecological conditions.

Throughout the decade of the pre-Chornobyl period the average annual electric power output growth in the world was around 3,7% and in the former USSR - 3,8%. In a number of states (Brazil,China,India,South Africa) the growth rate was much higher than that. France should be noted separately in this respect, where the annual output growth in the course of 10 years was around 6% due to intensive development of nuclear power. It is worthwhile mentioning, that in the majority of states-large producers of electric power, the share of nuclear power plants in the total energy output is higher than in the world in general.

Thus, the energy production in the world is growing at a relatively stable high rate. At the same time, certain measures taken by some states on savings of power and reduction of energy consumption made it possible to slow down the energy production growth for some negligible period, however these changes never really affected the growth dynamics.

Specific calculations, performed with respect to conditions of development of the Russian Federation, show that in order to tackle the economic and social problems, energy production output should be increased by no less than 3% annually with a simultaneous provision of a complex of measures on energy saving, otherwise the above stated figure would have to be doubled.

The program of economic reforms in Russia should be based on reliable power supply to all elements of the industrial and economic complex, which for Russia's enormous scale is hardly possible to provide without a clear concept of the state power production policy, having stable long-term goals.

The concept of nuclear power development defines its place and role in the state fuel-energy production system and lines of its development as well as sets forward practical tasks, driven from the long-term strategic goals.

This concept should be regarded as a flexible strategy of the branch development, periodically specified , refined and planned for practical implementation in the form of The Complex Program of Nuclear Power Development in the Russian Federation for the period of up to 2010, elaborated by Minatom.

Nuclear power, despite its small input into the energy state balance(3%), holds at present key positions in a number of the most important electric-power systems in Russia(North-West, Central,Middle Volga) and for the perspective is economically most feasible source of power supply for many regions. With view of well-known advantages of nuclear power the share of power production from nuclear sources may grow up to 30% for Russia in general, and up to 50% for it's european part. At the same time, the share of nuclear power in the state fuel balance,including district heating, may reach 10%.

Nuclear power development for the period of up to 2010 (the program's main goal) should be maintained within such a framework,that would, first of all, compensate the capacities of the decommissioned NPPs and also replace a number of power units of the thermal plants on solid fuel with resources exhausted. The general capacity increase at the operating NPPs should be at the same time relatively insignificant. On the other hand, efforts should be integrated to provide for its safe operation and growth, international evaluation of any new line of its development and establishment of international cooperation in the field of its safe implementation.

The major predictable indices of the nuclear power development program can be characterized by the following figures:

- NPPs' installed capacity:	1995 - 23,2 Gwt
	2000 - 27,4 Gwt
	2010 - 40,0 Gwt.
- Power production:	1995 - 139 billion kwt/h
	2000 - 158 " - "

2010 - 259 billion kwt/h.

- Nuclear District Heating Plants' installed capacity should by 2010 be 2,58 Gkal/hour.

With respect to real conditions of nuclear power and economy in Russia the program incorporates the following development stages:

- 1993-2000: during this "forced" or "renovation" period upgrading of the operating units with increased safety provisions should be accomplished. NPPs'capacity growth should be negligible and mostly related to continued construction of the already commenced sites. At this stage head end units of the new ("safety increased")generation are constructed and developed on the basis of the newly adopted technologies. This would provide for stable development of nuclear power in the forthcoming stage.

By 2000, start-up of four VVER-1000 reactor-type power units is being planned, as well as of one modernized RBMK-1000 reactor-type unit, two Nuclear District Heating Plants(AST-500), two "fast" reactors BN-800 for the Urals region and one power unit of the new generation with a 630 Mwt capacity.

By the end of the given period head end small-power units should be constructed for power supply to remote and inaccessible areas.

The main strategic goal of the first stage should be real demonstration of the possibility to introduce safe and economically feasible nuclear power sources into the state power production system.

- 2000-2010: this period is characterized by the capacity growth on the basis of the new generation units. A planned decommissioning process is started for units, having exhausted their resources.

A total number of twenty power units is planned for commencement at this stage with a capacity of 1000 Mwt each(8 out of 20 would be replacing Thermal Power Plants), as well as four 600Mwt units of the new generation, four units on the basis of VVER-440 reactor, two MKER-800(channel-type)units, four AST-500 and three "fast" commercial reactors.

With a design life period being 30 years, by 2010, 14 power units with a total installed capacity of 7400 Mwt would exhaust their resources.

The stage after 2010 is defined as the period of large-scale nuclear power production. Its technological basis would be set up at the previous stage and would much depend on the problems of fuel supplies and environment protection.

The above stated data shows that the main efforts would be concentrated in the pressurized water sector, that would allow to add up to the existing positive national experience, scientific-technical & industrial stock by involving extensive international achievements and cooperation. Pressurized water reactors of the new generation besides a qualitatively higher safety level also have a number of new important consumer characteristics: the primary equipment life period increased up to 50-60 years, optimized operating conditions, reduction of the operating personnel,and a significant(by 10 times) reduction of radioactive wastes produced.

Two levels of power for the VVER reactors are defined by the demands of the specific power supply systems in Russia and those of foreign customers. The reactor power reduction and decrease of power density in the core provide for additional opportunities of a substantial safety upgrading.

Works would be continued on the development of a competitive fast neutron reactor for fuel breeding,based on BN type of reactor with the goal of the fuel cycle closing, including effective plutonium burning and long term fuel self-supply for the nuclear power.

Safe development is the key-element for the nuclear power in Russia, focused on the construction of new power units,capable of replacing obsolete ones in the energy system.

When developing a new generation of NPPs its necessary to advocate designs, that by their physical properties, technological characteristics and passive character of the safety systems implemented, would be capable of practically excluding possibilities of heavy accidents. The important condition for future NPPs safety provision is the correct safety substantiation at the stage of design and project quality assurance at the stage of construction. Effective organizational and technical means of NPPs protection against willful harm or destruction(terrorism) are being stipulated.

In the period of up to 2000 the nuclear power may be developed in an open fuel cycle. In order to reduce demands in uranium mining and tackle the problem of radioactive wastes management in the process of future development of nuclear power, it's necessary to prepare the technical and industrial basis for the transition to the closed fuel cycle. Without simultaneous use of regenerated uranium and plutonium a closed fuel cycle is both economically and environmentally not feasible. The economic feasibility of a closed cycle would show its maximum advantage in the development of nuclear power on fast neutrons with a broad-scale fuel regeneration.

Radioactive wastes, produced at the NPPs, are mainly classified as low and medium wastes with a less than 30 years period of semi-decay. The amount of high-wastes produced is less than 1%. The task for the nearest 3-5 years would be to supply all operating NPPs with modern closed systems of solid and liquid waste conditioning and prepare them for long-term centralized storage. The concept of radioactive wastes management has been worked out as a separate document, that would serve as a basis for the program practical implementation.

Technical complexity, nuclear hazards and resource consumption of the nuclear power and technology require broad international cooperation in the course of national programs' development. The international nature of nuclear power sets forward as a primary goal the correlation of activities in the provision of safety for its development. An important role in resolving this task belongs to international organizations and above all to IAEA.

Nuclear power development in the Russian Federation should provide for the possibility of not only preserving the existing interstate(in the framework of CIS) and international markets, but also of their further expansion.The chance for such an extension exists.

The level of the perspective national technical solutions on NPP safety equals the best western versions and there is no ground to focus new generation NPP designs for the nuclear power in Russia on western companies' developments. Nevertheless, various forms of western firms' participation in the national works are feasible within the framework of international cooperation.

The program also contains the major requirements for NPP personnel training, necessary R & D complex, development of the experimental research basis, international trade, social and legal activities.

The expert analysis has proved the capabilities of the industrial branch to execute the complex program on condition of a guaranteed safety provision for nuclear power development.

It should be also mentioned that the given program already finds a practical implementation: at the end of 1992 the Government of the Russian Federation passed a resolution, that is in fact a program for the construction of NPPs in Russia till 2010. The implementation of this program is planned in strict accordance with the existing laws of the Russian Federation in the area of environmental protection, in compliance with the public opinion and with availability of subsequent positive decisions from local and regional authorities on the construction of nuclear power sites on their territories.

The necessary requirement for accepting the technical project for the construction of any type of NPP is the availability of the positive conclusion from the State Environmental Expertise Commission.

The given resolution combats stagnation in this branch of industry, demonstrates real possibilities to introduce safe and economical power sources,based on nuclear fuel,into the state energy system. It also provides for a non-stop development of nuclear power, that combines upgrading of the existing & creation of new, modern technologies.

L I S T

of appendixes to the paper "Nuclear Power in Russia today and tomorrow"

Appendix 1: The major predictable indices of the Program

Appendix 2: The schedule of commissioning and decommissioning of the power units at the NPPs till 2010.

Appendix 3: The main technical characteristics of the facilities

Appendix 4: NPPs' operating data for 1992

APPENDIX 1

THE MAJOR PREDICTABLE INDISES OF THE PROGRAMM

INDICES	YEARS AND PERIODS				
	1993	1995	2000	2005	2010
1. Installed NPP capacity (by the end of the year), hW	20,242	23,242	27,472	37,121	39,941
2. Installed capacities commissioning, hW	---	3,0	4,23	13,339	7,432
3. Installed capacities decommissioning, hW	---	---	---	3,75	4,612
4. Installed NDHP capacity hcal/h (by the end of the year)	---	---	0,86	2,58	2,58
5. Commissioning of the capacities at NDHPs hcal/h	---	---	1,72		
6. Power production at the NPP, billion KW x h	120	139	158,6	213,9	259,1
7. Thermal energy output, hcal					
TOTAL	3,6	3,6	6,8	13,0	19,6
NDHP	---	---	2,8	7,6	12,6

APPENDIX 2

THE SCHEDULE OF THE COMMITIONING AND DECOMMITIONING OF THE POWER UNITS AT THE NPPs TILL 2000

n/n	Name of power plant Unit no.		Capacity KW	Dates of commitioning and decommitioning of the units				Stage of completion
				1992 1995	1996 2000	2001 2005	2006 2010	
1	2		3	4	5	6	7	8
1	Balakovskaya	* 1	1000	---	---	---	---	
		* 2	1000	---	---	---	---	
		* 3	1000	---	---	---	---	
		4	1000	X--	---	---	---	90%
		5	1000		X--	---	---	30%
		6	1000			X--	---	0%
2	Dalnevostochnaya	1	600			X--	---	0%
		2	600				X--	0%
3	Kalininskaya	* 1	1000	---	---	---	---	
		* 2	1000	---	---	---	---	
		3	1000	X--	---	---	---	70%
4	Kurskaya	*1	1000	---	---	---	-X=	
		*2	1000	---	---	---	-X=	
		*3	1000	---	---	---	---	
		*4	1000	---	---	---	---	
		5	1000	X-	---	---	---	60%
5	Novovoronezhskaya	*3	417	---	---	-X=	===	
		*4	417	---	---	-X=	===	
		*5	1000	---	---	---	-X-	
		6	1000			X--	---	0%
		7	1000			X--	---	0%
6	Kolskaya	*1	440	---	---	-X=	===	
		*2	440	---	---	-X=	===	
		*3	440	---	---	---	---	
		*4	440	---	---	---	---	
		5	630			X--	---	0%
		6	630			X--	---	0%
		7	630				X==	0%
7	Karelskaya	1	600			X--	---	0%
		2	600				X--	0%
8	Primorskaya	1	600			X====	=====	0%
		2	600				X==	0%
9	Leningradskaya	*1	1000	---	---	-X=	===	
		*2	1000	---	---	-X=	===	
		*3	1000	---	---	---	X--	
		*4	1000	---	---	---	---	
		5	1000(800)			X--	---	0%
		6	1000(800)				X--	0%

will be accepted according to the results of technical - economic research carried out on the assignment of the RF Government for the regions of the European part of the country and the Far East.

3) The nuclear development of the North-West region along with that of th LeningradsKaya NPP will be carried out pursuant to the Nuclear Power programm that is now being developed for this region.

APPENDIX 3

THE MAIN TECHNICAL CHARACHTERISTICS OF THE REACTOR FACILITIES

	V-1000 (NP-1100)	V-500	VPBER-600	AST-500M	BN-800	MKER-800
Thermal capacity	3000-3300	1800	1800	500	2100	2450
Primary curcuit circulation	PCP	PCP	PCP	Natural	PCP	Natural
Number of loops	4	4	--	--	3	16
Primary curcuit pressure(MPa)	15,7	15,7	15,7	2,0	0,88	7,0
Core inlet temperature, C	296,9	293,9	294,4	131	354	268
Core outlet temperature, C	326	323,3	325,0	208	547	285
Steam pressure(MPa)	7,35	7,06	6,5	---	13,7	7,0
Steam production capacity, t/h.	6696	3570	3350	---	---	4600
Steam temperature, C	289,2	286,4	305	---	490	270
Fuel	UO-2;UO-2 +PuO2	UO-2	UO-2	UO2	PuO2; UO2	UO2
Number of fuel assemblies	211	163	151	121	517	1580
Power density	91	65,4	69,4	27,4	460	Fuel 280wt/cm
Fresh Fuel Enrichment, %	3,6	3,6	4,0	2,0	15,7 18,6 24	2,4
Operatign period, (years)	4-5	5-6		6	4	0,25
Period between refuelings(years)	1-2	1	1,5-2	2	0,3	*
Power variation range, %	30-100	30-100	30-100	10-100	10-100	30-100
Power variation rate	2-10	3	2,5-5	0,4	---	**
Life period of the reactor vessel(years)	60	60	60	30	60	50
...of the reactor plant	50	50	60	30	60	50
Designed Earthquake(units) MSK-64	8	8	8	---	8	8

* Refueling on the operating reactor

** Not limitted witin the range of 50-100% of its nominal capacity

10	Severo-zapadnaya (Sosnovy bor)	1	630		X--	---	---	0%
11	Rostovskaya	1	1000		X--	---	---	80%
		2	1000			X--	---	
12	Smolenskaya	*1	1000	---	----	---	---	
		*2	1000	---	----	---	---	
		*3	1000	---	----	---	---	
13	Beloyarskaya	*3	600	---	----	---	-X=	
		4	800		X---	---	---	
14	Bilibinskaya	*1	12	---	----	-X=	===	
		*2	12	---	----	-X-	===	0%
		*3	12	---	----	---	-X=	
		*4	12	---	----	---	-X=	
		5	32			X--	---	0%
		6	32			X--	---	0%
		7	32				X--	0%
15	Voronezhskaya AST	1	500		X---	---	---	80%
		2	500		X---	---	---	0%
16	Tomskaya AST	1	500			X--	---	0%
		2	500			X--	---	0%
17	Habarovskaya AST	1	500			X--	---	0%
		2	500			X--	---	0%
18	Yuzhno-Uralskaya	1	800		X---	---	---	10%
		2	800			X--	---	0%
		3	800			X--	---	0%
Measured Capacity at the end of the operation period(hWatt)-electrical -thermal			20,29 (1992)	23,24	27,48 1,0	33,12 2,0	30,94	
Operating as substitutes for Hydrolic Power Stations								
19	Nuclear Power Plant of RF Centre		1000			X--	---	0%
			1000			X--	---	0%
			1000				X--	0%
			1000				X--	0%
20	Nuclear Power Plant of RF Centre		1000			X--	---	0%
			1000			X--	---	0%
			1000				X--	0%
			1000				X--	0%
Measured Capacity at the end of the operation period(hWatt)-electrical -thermal			20,29 (1992)	23,24	27,48 1,0	37,12 2,0	39,94	

"---" - Power unit operating
"===" - Power unit decommitioned

Note: 1) The actual capacity of the production complex of MINATOM allows the earlier large-scale introduction of new power units.
2) The specified informatoin on the commitioning of the new power units

Appendix 4

NPPs' operating data for 1992

Throughout 1992 28 power units of 9 russian NPPs with the total installed capacity of 20242 Mwt produced 119624,7 million Kwt/h of electric power. The plan for power production at NPPs has been accomplished.

In the overall amount of power produced the NPPs share is 11.8%.

The avilability coefficient was 67,3%(at the level of 1991),
69,4% for NPPs with VVER reactors,
65,7% for NPPs with RBMK reactors.

The availability coefficient for NPPs with VVER reactors lies in the range from 61,8% to 73,3% and for NPPs with RBMK reactors- from 56,9% to 84,4%.

The highest availability coefficient was

There were 205 incidents at the NPPs in 1992, 33 whereof occurred through the fault of the personnel (172 in 1991 and 48 respectively). 146 incidents occurred at the NPPs with the VVER type reactors and 59 at those with the RBMK type reactors. (The total of the VVER type power units currently operating is 12, RBMK-1000 - 11, EGP-6 - 4 and BN-600 - 1).

The incidents have been assessed against the international INES scale as follows:

-- 3 second level incidents (mild)

-- 28 - first level (insignificant)

-- 174 - zero level (not affecting the safety)

In 1992 the radioactive emmissions of all the Russian NPPs did not exceed the internationally accepted norms. The maximum iodine emmission level ammounted to 22% and of the inert gases to 55% of the accepted norm.

THE STATUS AND PROSPECTS FOR NUCLEAR POWER DEVELOPMENT IN CHINA

JIANG Xinxiong
President
China National Nuclear Corporation

April 1993

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ABSTRACT

A brief introduction is given, at first, to the status of nuclear power generation in China since 1980's, in which the emphasis is put on the progress of Qinshan NPP, a prototype 300 MW (e) PWR project, and Daya Bay NPP, a commercial 2 × 900 MW (e) PWR as a JVC project between the mainland of China and Hong Kong. A general description follows on the program for development of nuclear energy in China around the year 2000, including Qinshan phase Ⅱ 2×600 MW (e) PWR project, which has already been started this year with the detailed design and the site excavation. Meanwhile, upgrading and expansion of the nuclear fuel cycle, which was initiated in 1950's, are parallelly being carried on to meet the demand of nuclear power generation. The introduction is concluded with a briefing on the national policy for development of nuclear energy and ensurance of nuclear safety.

A light is shed upon, in the following part, the efforts for China to strengthen its international cooperation in the field of nuclear energy and nuclear safety since 1980's, as well as the contribution made to the NPT based upon the national " further reforming and more open policy ", i. e. the policy of enhancing international cooperation on the basis of self-reliance for development of nuclear power, the policy of not advocation, encouraging or going in for nuclear proliferation and the principle for nuclear import and export. A sincere wish is expressed before the end that China is willing to promote its international cooperation with foreign countries for developing nuclear energy, and ready to make its due contribution to the benefit of mankind.

Mr. Chairman,

Ladies and Gentlemen:

It is my great pleasure to head a Chinese delegation for participating in the 26th JAIF Annual Conference. First of all, I would like to express, to Mr. Chairman and the organizers of the Conference, my cordial thanks for being invited to the Conference, and my heartfelt congratulation on the opening of the Conference.

Mr. Chairman, may I take this opportunity to have a brief introduction on "the Status and Prospects for Nuclear Power Development in China".

A. The Status of Nuclear Power Development

As an important part of electricity industry, the nuclear power generation in China is just at its beginning. As known to all, there have already been three NPP being at different stages for the moment:

The first: the Qinshan Phase I 300 MW(e) NPP.

As a prototype PWR project, it was designed and constructed mainly on our own, and successfully connected to the grid on December 15, 1991, implying the ending of a history with no nuclear power generation in the mainland of China. For this project, the experience and achievement in developing nuclear science and technology accumulated in practice of more than 30 years have been adopted, and what is more, according to a statistics, over 400 R/D items have been carried out by more than 100 domestic institutions to support this project. About 70 percent, in total value, of the equipment were supplied by domestic manufacturers, while the project management, civil engineering, installation and commissioning were undertaken by Chinese engineers and workers. At the same time, much attention was devoted to absorption and adaptation of foreign experience, and some of the main equipment were imported and advanced techniques transferred from foreign countries. The Qinshan NPP was connected to the grid on December

15, 1991 with 15 percent of the full power, followed by a testing and experiment program consisting of 450 items for commissioning at five different power levels such as 15, 30, 50, 75 and 100 percent respectively.

According to a preset time schedule , an overall examination and overhauling program was implemented after completion of off-loading experiment at full output. The program consisted mainly of three aspects: (1) Overall examinations on the systems, equipment and instrumentation, including in-service inspection on the steaming generators and the heat exchangers of equipment cooling system, as well as the replacement of the UPS; (2) Systematic on-job re-training of the personnel in order to guarantee their quality of operations and the culture of nuclear safety; (3) Complement or perfection of the operation-oriented documents and QA/QC systems based upon summarisation of the experiences gained in the commissioning period, in order to establish a better basis for the forthcoming formal operation.

The Qinshan NPP had been restarted in March, and is expected to enter its formal operation one year after a trial operation in accordance with the regulation set by National Nuclear Safety Administration.

The second: the Daya Bay 2×900 MW(e) NPP.

It is a commercial PWR Nuclear power plant constructed and to be operated by Guangdong JVC. Most of the equipment were procured either from Framatome of France for the Nuclear Island or from the GEC of U. K. for the Conventional Island, and from many other countries for the BOP, while the project management, civil engineering, installation and commissioning are undertaken by a joint team of the foreigners and Chinese or the JVC itself. The project is being proceeding smoothly. For the first unit, the functioning test of the Nuclear Island in thermal condition had been completed; According to the schedule, it could be expected getting connected to the grid by the end of this year. The schedule for unit 2 will be half a year later than that of unit 1, i. e. connection to the grid will be in the mid 1994.

The Third: the Qinshan Phase Ⅱ 2×600 MW(e) NPP.

By persisting in the policy "Strenthening International Cooperation on the Basis of Self-reliance", this project will be speeding up. The Basic design had been approved last year by the authority and the detailed design is being carried on. A series of R/D programs have been settled down. Arrangement for procurement has been made. The contract for the site excavation has been signed, and will soon be executed. The timing shows that the first barrel of concrete will be pouring in the mid 1995. Unit 1 will be commissioned by the end of this century followed by unit 2 one year after.

Besides the above-mentioned three NPP either in commissioning or under construction, a few more will soon come true. For example, the Recommendation for Daya Bay Phase Ⅱ 2 × 900 MW (e) Project was approved, preparations are proceeding and the negotiation for cooperation with foreign companies has begun. In the meantime, negotiation is under way with Russia for importing a 2×1000 MW(e) PWR NPP to be located in Liaoning Province. The Bilateral Agreement Between Sino-Russian Governments on the Cooperation for Nuclear Power Plant was concluded last year, which will be continued with the negotiation on the technical and commercial provisions.

Feasibility studies are being undertaken for building up some other NPP's in the southeastern coast areas, where the ecomony is growing very quickly but the conventional energy resources are rather limited. Both siting and financing are being stepped up in these provinces.

It can be predicted that, with a faster growing of national ecomony in China, development of the nuclear power should be on a fairly large scale with a speeding-up rhythm from this decade.

B. Nuclear Fuel Cycle

A fairly integrated system of nuclear fuel cycle had been founded before 1980's through sustained efforts of over 30 years. The system consists of

Uranium Resource Exploration, Mining and Processing, Chemical Conversion, Enrichment, Fabrication, Reprocessing of Spent Fuels, Radwaste Treatment and Disposals, which provided an essential precondition for initiation of nuclear power program in China. A large number of R/D items was arranged and a program of upgrading and expansion of the cycle was carried out from the very beginning of the nuclear power program. The objective is to realize the principle "Nuclear Fuel Supply Stands on the Domestics". An encouraging progress has been made from then on and is enumerated as follows:

(a) Uranium Exploration and Mining

Those backward techniques employed in the existing processes have gradually been replaced with more advanced ones to catch up with the state-of-the-arts, of which the application of leaching technology is a typical one. The heap leaching has been put into industrial application while the in situ leaching is now at the engineering stage.

(b) Separation of Uranuim Isotopes

Significant efforts are being made to develop the centrifugal technique while the diffusion one is continued to be upgraded. Simultaneously, the basic research is being under way for application of the laser technology to the enrichment and has reached a new stepstone on the road of its advance.

(c) Fabrication of Fuel Assemblies

With the start of nuclear power program, a series of R/D as well as engineering of the fuel fabrication was implemented. Hard work lasted for years and a production line was built up in Yibin of Sichuan Province which was supposed to play an important role in Qinshan 300 MW(e) PWR project. The assemblies for its initial core was supplied by Yibin Fuel Plant (YFP) where the assemblies for its first reload are being manufactured. A contract for Technology Transfer and Cooperation was signed two years ago, according to which the design and manufacture technology of the fuel assemblies for 900 MW(e) PWR will be transferred and the production line will be upgraded so that the fuel assembly for the reload of Daya Bay NPP could be supplied by a Chinese manufacturer. The upgrading will be finalized in 1996, however, by completing the first stage of this project it can be expected to supply the reload to Daya Bay NPP as scheduled, and moreover, YFP Project will play an important role in standardization and systematization of the fuel assemblies for 300, 600, 900 MW(e) PWR NPP.

(e) Reprocessing of Spent Fuels

It was decided that the policy of reprocessing would be adopted in the end of the cycle, which was resulted from an overall study and review carried out by our scientists and engineers on the basis of domestic and international practices. The engineering for reprocessing of PWR's spent fuels was proceeding based on the achievement gained from reprocessing of spent fuels with a shallow burn-up. A pilot reprocessing plant is now under construction in Gansu Province and expected to be in operation around the year 2000; while a commercial one should be set up in the first decade of the next century.

(f) Treatment and Disposal of Radwastes

Considerable attention has been paid to the management of radwastes, while the nuclear industry and nuclear power generation are developed, in order to protect the environment and the public health.

The following principles are taken for management of the radwastes:

1. Minimization of radwaste quantities;

2. Distinct division of the responsibilities: The producer shall be the responser;

3. Concurrent design, construction and operation of the facilities for main process and for Radwaste treatment;

4. Classification for management;

5. Promulgation of legislation for release under independent supervisory bodies;

6. Solidification for final disposal with a long-term monitoring;

Variety of techniques are selected for treatment of differently classified radwastes:

1. Decay in storage, absorption by the active carbon or filtration for airborne radwastes.

2. Cementation and bituminization are used for solidification of the liquid radwastes at a low or medium level.

3. Vitrification is selected for those at a high level.

For disposal, in situ temporary storage and regional repository facilities are planned to build up for solid radwastes at low or medium level;

The concentrated deeply geological disposal will be adopted for the high level wastes.

C. Prospects for Nuclear Power Development

Mr. Chairman,

Ladies and Gentlemen:

China is a developing country. The "Further Reforming and more open policy" is being insisted on and all efforts are being focused on development of the national economy. Faster and continued growing of the economy can be expected, calling for a greater growth factor of the power industry. It is true especially to the southeastern coast area. However, either the fossil or the hydraulic power resources are rather limited in this area. Sole dependence on the conventional resources could bring about serious transportation and airpolution problems. The conclusion is: developing nuclear energy will be the best way to have this area cast off the difficulty in shortage of the power supply. The strategy for developing the power industry in the coast area has just been shifted to "The same priorities to the coal fire, hydraulic and the nuclear power in light of the local conditions". Preparations such as siting and financing are being carried on for NPP at present in Fujian, Jiangsu and Shandong Provinces as what were being done a few years ago in Guangdong and Liaoning Provinces.

" Strenthening international cooperation on the basis of self-reliance" is the current policy for developing nuclear power generation in China. In accordance with the policy, it wil be the first step mastering design, manufacture, construction and operation of 300 MW(e) and 600 MW(e) PWR NPP through the practice of building up Qinshan Phase I and Phase II within this century, resulting into a higher portion of home-made equipment, a shorter period of construction and a lower cost which will surely be favourable to their spreading. On the other hand, it is also intended to import, as a whole or in partial, equipment for large scale NPP. A firmer foundation can be established by the efforts in duel for accelerating the development of nuclear power in the next century.

Financing and accumulation of experience will be the most challenging topics for our nuclear power program. We are expecting for a total 6000 MW (e) nuclear power capacity installed in China by the end of this century.

Mr. Chairman:

Nuclear safety and reliability are more and more concerned by the public. "Safety First and Quality First" is consistently pursued as a foundamental principle throughout the practice of nuclear power development in China. A national supervisory body-China National Nuclear Safety Administration (NNSA), independent of the CNNC, has been founded before implementation of the nuclear power program; Promulgation of legislation has been completed for nuclear power and an adequate quality assurance system has been formed. At the same time, much efforts are devoted to explore new technology for power reactors with the inherent safety performance.

D. Foreign Policy and International Cooperation in the Nuclear Field

As known to the world, China is one of the nuclear weapon possessive countries. However ,China's nuclear industry has been concentraed itself on peaceful uses of nuclear energy since 1980's. China consistently stands for a complete prohibition and thorough destruction of nuclear weapons. And during the past 20 years or more unremitting efforts have been made to assume its responsibility and obligation of non-proliferation of the nuclear weapons, as well as promotion of nuclear disarmament. According to this policy, China has made its contributions as follows:

(a) Declaration of neither advocating, encouraging or going in for nuclear proliferation, nor helping any other nations develop nuclear weapons, in the early 1980's;

(b) Join in the IAEA, taking an active part in worldwide nuclear activities, in January 1984;

(c) Conclusion of the voluntary offer safeguards agreement with IAEA on civilian nuclear installations in China ,in September 1988;

(d) Accede to the "Convention on the Physical Protection of Nuclear Material ", in March 1989;

(e) Formation of the three principles for nuclear export, i. e. for peaceful uses only, subject to the safeguards by IAEA and no retransferring to any third corntry without permission in advance;

(f) Official signature on " Non-Proliferation Treaty" (NPT) in March 1992.

Mr. Chairman,

Ladies and Gentlemen:

With an independent nuclear foreign policy, China has strictly fulfiled its obligations of non-proliferation, insisted on its three principles for nuclear exports. On the other hand, China stands for an extensive international cooperation for peaceful uses of nuclear energy, particularly with the developing countries in order to make the nuclear power benefit to human beings, although the nuclear power program in China would depend mainly on self-reliance. Up to now, China has concluded inter-governmental agreement on the cooperation for peaceful uses of nuclear energy with 12 countries, and established freindly relations for nuclear affairs with more than 20 countries and regions. I believe that a more extensive international cooperation will have mutual benefits. In fact, during the construction of Qinshan NPP , a large number of foreign experts, including those from Japan or sent by IAEA, had been involved for technical services and consultations, and many Chinese engineers had been sent abroad for studies or training. It will be the same during the implementation of our future nuclear power program. All countries, including Japan and those in Asia, are warmly welcome to be involved in promotion of nuclear power development in China. China obliges itself to peaceful uses of techniques transferred as well as equipment and products imported for its nuclear power development. China is also willing to extend cooperation with the developing countries in developing their own nuclear energy for peaceful purpose, and is ready to make its due contribution to the benefit of mankind.

Mr. Chairman,
Ladies and Gentlemen:

Thank you for your attention.

JAIF 1993

By Yannick d'ESCATHA
Deputy Chairman

COMMISSARIAT A L' ENERGIE ATOMIQUE

1. The French nuclear programme : present status

France, facing the same scarcity of domestic energy resources as Japan, has conducted its energy policy for more than 20 years with two major guidelines :

- improving its energetic independence taking into account its lack of fossile resources,
- preserving the environment.

The approach chosen to fulfill the first goal has been to resort to nuclear energy by launching an important nuclear reactor programme, which allowed France to increase its energetic independence from 27% in 1980 to 49% in 1992, and by closing the nuclear fuel cycle which permits to recover the fissile materials for further use. This programme has been implemented on the same lines as chosen by Japan : standardization of nuclear reactors, construction of several units on each site, development of a consistent fuel cycle industry.

As to the second objective, it is worth outlining that the use of nuclear energy for electricity production has so far reduced the CO2 emission in France by more than 230 MT. Moreover the reprocessing strategy which, aside from recovering plutonium and enriched uranium, involves the management of wastes according to their radioactive and physical characteristics, aims finally at minimizing their impact on the environment thanks to optimization of their final confinement.

The context prevailing when the nuclear programme was launched has considerably changed with time. In particular, due to the Tchernobyl accident and its international consequences, and more recently to events having occured in the former USSR, public opinion has become more and more sensitive to issues such as reactor safety, environmental protection on a long term range and subsequently to waste management problems, and to the unavoidably international dimension of nuclear energy.

Consequently, despite the present technical and industrial success of nuclear energy and despite its proven economic efficiency in countries like Japan and France the possibility of heading for further developments of nuclear programs is pending upon the ability to convince public opinion that nuclear energy is safe both in a short and in a long term perspective.

In this frame let us briefly point out the present achievements and the pending question in the case of France.

As to achievements, the following main points can be quoted :

. 54 PWR units (900 MWe and 1 300 MWe) presently in operation produce approximately 75% of the french electricity consumption. In the French situation, the cost of a kilowatt hour of base load electricity produced from a nuclear plant put into service in the coming years has a projected competitive margin of 30%, when compared with the costs of electricity from combined cycle gas and coal plants ;

. The maximum burn-up reached by the standard UO2 fuel has been progressively increased from 33 000 MWd/t to around 45 000 MWd/t without meeting any significant problem ;

. The fuel cycle is closed satisfactorily on an industrial scale : the La Hague plant owned and operated by COGEMA has so far reprocessed more that 5 000 tons of irradiated fuels and vitrified 1 700 blocks of high level wastes ;

. Plutonium recycling in PWR is practiced since 1987 at a rate of 30 percent MOX fuel assemblies in the core of 900 MWe reactors in EDF plants. Today, five of the sixteen units that have been approved for MOX fuel operation are loaded with this fuel ; in four of them the proportion of MOX has reached the authorized equilibrium value. These five reactors are operated in base load with a third of the core reloaded annually, but two of them are authorized for load follow operation for demonstration purposes. The maximum authorized value of average fuel assembly burn-up, 36 000 MWd/t, has been effectively achieved in three units without any problems during irradiation.

. To dispose of low level wastes, a new storage center with a 1 million m3 capacity has been put into operation by ANDRA (Agence Nationale pour la Gestion des Déchets Radioactifs) near Soulaines (Centre de Stockage de l'Aube).

. During these last years, quite significant efforts have been made both at the governmental level and by the main nuclear actors (EDF, Industry, CEA) to improve the "transparency" of nuclear energy, notably by setting up permanents means for public information and for local concertation.

Despite these achievements, there are various questions which have been raised during the implementation of the french nuclear programme, and which must be answered for any further nuclear energy development, not only from the technical standpoint but also from the public acceptance one. The main questions are :

. the safety of future reactors, which still has to be increased, mainly after the Tchernobyl accident, and even if the safety level of today's French PWR units is fully satisfactory ;

. some technological problems encountered with present PWRs operation, which are or are being mastered. Among the problems, one can mention the steam generator replacement which concerns every country equipped with PWRs, and the small cracks found in a few of the control rod guide sleeves fitted to the pressure vessel heads of some French PWR units ;

. problems related to plutonium recycling. Presently in France, the use of MOX fuel is limited by the fabrication capacities (Belgonucléaires's Pu unit and Cogema's Cadarache workshop). This limitation will disappear when Cogema's plant under construction in Marcoule with a capacity of 120 t/year, enters into industrial operation (1995). Beside this limitation, there are other factors which need to be improved in order to benefit totally from plutonium recycling in PWRs. Some of them are related to specific features of existing reactors, others are due to the short amount of experience with MOX fuel ;

. Uncertainty regarding the future development of Fast Reactors. It is clear that in the present conditions there is no urgent need of plutonium breeders but that such reactors will probably be necessary around 2030 to cope with a worldwide increasing energy demand. In this context some countries have reduced or stopped their Fast Reactor programmes (Germany, UK).

As for the technical aspects, in spite of the overall satisfactory demonstration achieved with PHENIX, the problems encountered with SUPERPHENIX show that further experience is needed to master the framework of the European corporation for the EFR project indicate that Fast Reactors would be economicaly viable if built as a series.

On the other hand, due to their flexibility, Fast Reactors can be used as plutonium burners instead of plutonium breeders, thereby contributing in regulating the plutonium stockpile : this is an incentive to carry on with their development in a mid term perspective;

. public concern about the long term impact of the long lived high level wastes on the environment leads to further improving the management of these wastes notably by minimizing the quantities to be disposed in final repositories.

2 - Prospects for nuclear energy in France

The prospects for the nuclear energy in France take into account the specific characteristic of this country :

. the shortage of fossile ressources is and will remain a constraint which leads to resort for a long period of time to nuclear energy,

. the present contribution of nuclear energy to electricity generation (75%) is a top limit figure for France's nuclear capacity in the short and mid terms,

. public acceptance is a prerequisite for any further development of the French nuclear programm and public opinion has to be convinced that use of nuclear energy can be safe both in short and long terms. In this respect the management of the back end of the fuel cycle is a key point ;

. the achievements of the present nuclear programme and the problems encountered during its implementation show the directions in which further efforts are to be carried out.

In this context, the French nuclear programme will be carried on along the following lines:

. In spite of some technological problems encountered, such as those already mentioned, PWRs will remain the bulk of the French nuclear programme for a long period of time. Assuming a 30 years plan lifetime (possibly extended to 40 years for part of the existing units) the first replacements will take place around 2005-2010.

In the immediate future, EDF and FRAMATOME are carrying on the construction of N4 units (1 450 MWe) : two of them should enter into operation in 1995 and 1996 (CHOOZ B1 and B2), one has been ordered in 1991 and another one should be ordered in 1993 (CIVAUX 1 and 2). Four more N4 units are presently envisaged.

The PWR model to be used at the beginning ot the next decade, a 1 450 MWe four loops unit, is being studied in the framework of a German-French cooperation involving NPI, a subsidiary of FRAMATOME and SIEMENS, its mother companies and the German and French utilities. The corresponding project, EPR (European Pressurized water Reactor), takes advantages of the most advanced French and German models, N4 and KONVOY. This project will have to meet the requirements of the European utilities which are elaborated inside the European Utility Requirement groupe (EUR), gathering utilities from Belgium, France, Germany, Spain and the United Kingdom.

The first phase of the EPR project, corresponding to be conceptual design (definition of the major options), started in 1992, is ending now. It will be followed by the Basic Design phase (1993-1995) which will be concluded notably by the output of a preliminary safety report. The construction of the first unit is envisaged en 1998.

. In order to continue to fuel the PWR units in a secure and economic way, significant efforts are devoted to fully master the SILVA enrichment process which should replace in the future the gaseous diffusion plant operated by EURODIF. The feasibility of SILVA has been demonstrated recently within CEA on a laboratory scale.

. Fast reactors remain a French pole of interest.
In a short term perspective, the major concern is to be able to restart PHENIX and SUPERPHENIX. Indeed PHENIX, as a flexible demonstration plant, is a necessary tool for all the Fast Reactor studies, and SUPERPHENIX alone can provide the accumulated operating experience which is essential for mastering the technology of Fast Reactors and improving the solutions for any future design.

In the mid-range perspective, the efforts are now largely reoriented towards studying the feasibility of Fast Reactors devoted to the burning of plutonium and actinides in order to optimize the management of the plutonium stockpile and to contribute significantly to the elimination of long lived high level wastes. As to the technological aspects, these studies will take full advantage from the studies performed for the EFR project.

For the long term, the results achieved within the studies performed in the framework of European cooperation (France, Germany, The United Kingdom) for the EFR project provide a sound basis for further advances when they will become necessary. The corresponding options could be explored through cooperations with countries involved in Fast Reactor programmes, such as Japan.

. Due to the delay of introduction of Fast Reactors in the French nuclear system, the recycling of plutonium in PWRs plays an important part in the French nuclear strategy. Independently of the implementation of a large MOX fabrication capacity, presently under construction, the major concern is related to be improvement of the MOX fuel performances, so that this fuel reaches the same burn-up as the standard UO2 fuel ; 45 000 MWd/t in a first step, 55 000 to 60 000 MWd/t later on. On the reactor side, the goal is to increase the share of the MOX fuel in the PWR cores from 30% to 50% and possibly more.

. In order to respond to the public concern about the wastes and in particular the long lived high level ones, a law issued on december 30, 1991 identified three major objectives for research for the next fifteen years, before a new debate and possibly a final decision on waste disposal by the Parliament. These objectives are : improvement of the waste conditioning, extraction and incineration of the long lived wastes in order to minimize their long term toxicity, research performed in underground laboratories in order to characterize the capacity of geological structures to confine radioactive wastes (two sites have to be selected for these undeground laboratories, in concertation with the local population) ; last the study of conditioning and prolonged surface storage of waste. With regard to the incineration of long lived high level wastes, a report ordered by the Former Minister of Research and Space, M. CURIEN has notably concluded to the usefulness of experiments in Fast Reactors such as PHENIX and SUPERPHENIX.

3 - The research Programme on the back-end of the fuel cycle

To comply with the requirements of the december 1991 law related to the management of long lived high level wastes, CEA has launched an important and long term R&D programme, the so called SPIN programme, devoted to separation and incineration of these wastes.

This programmes includes two sub-programmes :

- In a short and mid term perspectives (1991-2000) PURETEX, aiming primarily at reducing the volume of waste from reprocessing from 1.5 m3 to 0.5 m3 per ton of reprocessed heavy metal. This value is to be compared with the 1.7 m3 announced for direct storage of irradiated fuel.
This result will be obtained by modifiying the PUREX reprocessing process (decreasing or eliminating sodium salt, new management of liquid streams) in order to be able to eliminate bitumen and by improving the conditioning of solid wastes (hulls compaction or melting for example).

- In a long term perspective ACTINEX, devoted to the separation and transmutation of long-lived elements in view of reducing waste toxicity by a factor of 100 and then 1 000 compared to direct storage, within 20 and 40 years respectively.

Our knowledge of the properties of elements in an aqueous medium, issued from the experience accumulated with the PUREX process, has led us to prefer this method over a non-aqueous one.

A first step consists in modifying the PUREX process in order to recover 80 to 95% of the neptunium and a large part of the technetium directly in the reprocessing plant.

The other long-lived elements and the residual Np will be extracted from fission product solutions.

The toxicity reduction factors indicated above imply a drastic limitation of secondary wastes. This is why the process based on solvent containing phosphorus has been excluded and research oriented towards an extractant of the fully calcinable diamide type, which allows extraction in a highly acidic medium and re-extraction in a low-acid medium, that is to say standard classical conditions in well known liquid-liquid extraction.

However in such a process, actinides and lanthanides are extracted simultaneously and have to be separated later, and the process is penalized by the fact that, for on useful part (the actinides) ten useless parts (the lanthanides) have to be extracted. Therefore, studies have been launched for specific extractants. Preliminary results have been obtained with picolinamides or azides.

For long-lived fission products the best results are obtained with macrocycles of the calixarene type. In particular, an extractant of cesium gives exceptional performances, even with a high sodium content.

Once separated, these elements can be mixed with fuel or manufactured into target elements for transmutation.

In the field of transmutation, studies are in progress in two directions : validation of the nuclear data which are necessary for incineration studies (cross sections, yields, decay data), parametric studies in view of evaluating the feasibility and the conditions of actinide incineration (reactor type ; PWR or Fast Reactor, fuel matrices ; UO2, MOX, metallic fuel).

The validation of nuclear data is based upon specific irradiation experiments, irradiated fuel analysis, and integral experiments performed in MASURCA and EOLE critical facilities.

From the parametric studies, among the first conclusions are the following ones :

. Actinides can be introduced homogeneously either into PWR UO2 fuel at the rate of about 1% or into FBRs at a rate of 2,5%. These contents are set to ensure reactor safety, taking into account modifications of the core parameters resulting from the presence of actinides.

. Homogeneous recycling does not affect the neutronic balance of Fast Reactors but requires to increase the PWR fuel enrichment by 1% (absolute value).

. Multirecycling is necessary if one wants to eliminate between 90% and 95% of the quantity of actinides loaded in the core.

An experiment called Superfact has been run in the PHENIX experimental Fast Reactor with the homogeneous concept involving elements Am and Np at low (2%) and high (40-45%) concentrations. This experiment has concretely demonstrated the feasibility of the fabrication, design and irradiation, up to about 6 atoms % of such fuels and their good behaviour with respect to standard pins. New studies are directed towards high transmutation efficencies, i.e. high burn-up (Superfact II experiment).

In the future, the irradiation of metallic targets is planned for CRIEPI (Japan), in association with the European Institute for Transuranium Elements (Euratom, Karlsruhe).

The same validation is being prepared for the PWRs with the ACTINEAU experiment in the OSIRIS research reactor.

In parallel the possibilities of advanced systems such as specific nuclear reactors and accelerators are investigated. These preliminary studies concern a fast reactor of the EFR type loaded with a (Pu/Am/Np/Cm) O2 fuel, and hybrid systems involving a proton accelerator and a subcritical medium, which are currently developed in the USA (LOS ALAMOS, BROOKHAVEN) and JAPAN (JAERI).

Concerning the development of reactors specifically oriented towards plutonium burning, CEA has quite recently started the CAPRA programme which aims at studying the feasibility of Fast Reactors optimized for that purpose,.The R&D studies concern on the one hand the cores loaded either with a MOX fuel, enriched to more than 30% in plutonium, or nitride fuel, or a new fuel without uranium, and on the other hand innovative fuel itself, with the definition and later on the validation of a new matrices (e.g. Ce, Y). This studies are to be supported by a specific experimental programme performed in MASURCA.

The other articles of the december 1991 law, related to the preparation of future repositories, have been studied for many years within CEA, in term of barriers, geological behaviours, long term behaviour of waste packages.
These studies are continuing in support to ANDRA (Agence Nationale pour la Gestion des Déchets Radioactifs), formerly a division of CEA and since december 1991 and independent organization which is responsible in France for radioactive waste management.
CEA R&D activities deal in particular with the long term behaviour of concretes, bitumens and glasses under irradiation and water leaching in order to know the source term evolution (radionuclide emission). Predictions derived from models will have to be confirmed in representative conditions, i.e by mean of underground laboratories, two of which should be identified within two years and commissioned well before the year 2000.

4 - Conclusion

In spite of the evolution of the international nuclear context since the enthousiasm of the sixties to the present cautious attitude which has appeared in several countries, the worldwide growing energy demand will necessitate in the future to take advantage of all available eneryg resources including nuclear energy. This applies in particular to industrialized countries which are short of fossile resources including, such as Japan or France. Beside this general trend, one has also to take into account the replacement of existing nuclear power stations. In France this replacement should start around 2005/2010. But continuation, and a fortiori further development of nuclear energy must take into account the strong concerns expressed by public opinions about reactor safety and waste management.

Dealing with the concerns implies to consider the international aspects of nuclear energy : international cooperations, on a bilateral or multilateral basis, or in the framework of international organizations (OECD, IAEA, CEC).

From the technical standpoint, often in the context of international cooperations, notably with JAPAN (PNC, JAERI,), CEA has engaged significant R&D programmes to solve the pending problems related to the development of nuclear energy, particularly in the key sector of the back-end of the fuel cycle, for which all the corresponding activities have been launched in a long terme perspective.

セッション1

わが国の原子力開発のあり方

＜問題提起＞

「原子力開発における長期計画の諸問題」

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原子力開発における長期計画の諸問題

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１．まえがき

長かった冷戦構造の崩壊をはじめとして、核兵器の拡散に対する懸念の高まり、地球環境問題の深刻化など、世界は今まさに大きな時代的・国際的な新局面を迎えつつある。このような環境の中で、わが国の原子力開発利用はどのようなものであるべきかについて徹底的に検討を深め、原子力開発利用に係わる基本方針及び具体的推進方策を見定めるべく、目下、長期計画の改訂のための作業が進められている。

原子力開発利用は社会・経済・技術などの広い分野にわたって極めて大きな役割と影響力をもつこと、また国際社会の中でわが国の果たすべき役割が次第に増してきていることなどから、この際、検討すべき重要課題も従来以上に多数にのぼると考えられるが、それらを要約・整理すれば、ひとまず次のようになるであろう。

２．検討すべき重要課題の広がり

まず長期的視点からの基本課題としては、第１に基軸エネルギーとしての原子力の確立が挙げられる。これには①原子力が将来にわたりどれだけのエネルギー供給の役割を担うのが妥当かを中心とした原子力の位置付けをより明確にすること、②どのような次世代炉が望まれるか、またそれらをどのように開発・実用化していけばよいかを検討すること、③立地を円滑に促進するための総合的な方策を検討すること、などが含まれる。第２に長期的展望に立った総合開発戦略の重要性が挙げられる。これには①高速増殖炉の開発の今後の進め方、②プルトニウム利用のあり方と具体的な進め方、③放射性廃棄物処理処分の進め方、そして④濃縮・燃料加工・発電・再処理・放射性廃棄物処理処分などの、整合性のとれた総合的かつ体系的な推進、などが含まれる。第３には基盤科学技術の推進の強化が挙げられる。これには①基礎研究の強化と原子力フロンティアの開拓、②先導的プロジェクトの推進、などが含まれる。第４には原子力を進めていく上での基盤条件の整備が挙げられる。これには①優れた研究者・技術者・技能者を確保し育成していくための方策、②研究者ならびに研究機関相互の国際的な連携と協力を強化するための方策、③原子力産業における研究開発力の維持・強化のための方策、などが含まれる。

次に、国際的視点からの基本課題としては、第１に核不拡散に対するわが国の役割の強化が挙げられる。これには①わが国の原子力開発の透明性を一層明確化することにより、わが国が一貫して原子力の平和利用に徹していることについての国内外の理解を深めていくこと、②世界的な核不拡散体制の維持・強化にさらに積極的に貢献していくこと、③高速炉技術の柔軟な利用や核物質の適切な防護措置の面での貢献、などが含まれる。第２には原子力技術先進国の一員としてのわが国の役割が挙げられる。これには①わが国の優れた技術や安全実績に基づいた国際的な原子力安全確保への貢

献、②これから原子力に取り組もうとする国々などへの支援、などが含まれる。

さらに、人々の理解と信頼を得るための視点からの基本課題について見ると、第1に人々の理解を増進することに関しては、①原子力を自らの問題として考える土壌を育成していくこと、②原子力と社会・地域との共生を目指し、その実現に向けて力を合わせること、などが挙げられる。第2に人々の信頼感を醸成していくことに関しては、①原子力施設の安全運転の実績を着実に積み重ねていくこと、②安全の確保と向上への努力を分りやすく示すことにより安心感を深めてもらうこと、などが挙げられる。そして第3に、原子力開発利用長期計画そのものが理解・支持されることが重要であり、そのために①できるだけ巾広く意見を求めていくこと、そして②さらに読みやすく、より広く注目される内容となること、などが重要であると指摘されている。

さて、以上に挙げた基本課題はいずれも重要であるが、とくに平和利用と安全性を将来ともに担保しつつ国際的相互理解のもとにグローバルな観点から、各国の原子力利用を円滑に推進していく上においては、長期的視野に立った原子力開発利用の国際的グランドデザイン、プルトニウムの利用と管理、原子力施設等の安全確保のための技術と体制、放射性廃棄物の処理処分などが主要な論点となる。さらに、原子力に対してより多くの人々の理解と支持を得ていくためには、学術・文化・社会活動全般にわたって原子力が十分に魅力的なポテンシャリティと極めて重要な役割をもつことを、先導的・基盤的な研究開発プログラムの実施や教育・普及活動を通じて徹底していくことが肝要であり、また原子力開発利用の実像を客観的かつ正確に社会に伝える上からは、マスメディアにとっての原子力のクレディビリティと分かりやすさを高めていくことが肝要である。以上の諸点については全般的に、原子力のグローバリゼーションの動向に鑑みて、より緊密で効果的な国際協力が不可欠であり、特に安全問題等に関しては国際的な基準や管理のあり方の検討を深めることが緊要な課題となっている。

原子力開発利用長期計画の検討においては、以上のような視点を踏まえながらも、さらに巾広く幾多の意見を受けつつ、活発な議論が進められている。それらのベースとして、現行のシステムや体制、従来からの計画や目標など、に照したさまざまな定量的な積み上げや評価が、並行して鋭意進められていることはいうまでもない。以下では、これらの中からいくつかの論点について、主な意見を紹介し、また私見も織り混ぜながら、問題提起に代えさせて頂きたい。

3．重要課題の中から －問題の所在と意見－

(1) 長期計画のあり方について

長期計画の検討に際しては、超長期にわたる世界の全体像の展望が不可欠である。その時間的スパンとして100年程度が適切か、1000年以上を考慮に入れるか、いずれにしても、そのような長い時間尺度で見た歴史観と未来観が要求されるのではないか。

ごく控え目に見ても、今後の世界的な社会・政治・経済・環境・人口動態などには、うねりや不安定現象があることであろう。しかし、エネルギー・環境問題等の検討にあたっては、安定的推移を念頭に置き、保守的な観点からフィロソフィーや政策を議論するのが妥当であろう。

100年後、200年後に至るエネルギー源の推移のあり方、南北間のエネルギー需給・

経済水準等の妥協点、原子力の国際的管理のあり方などに関するこれまでの展望や所説は参考になる。化石燃料、太陽等の再生型エネルギー、核融合を含めた広い意味での原子力、の三者には、それぞれ特長、リスク、あるいは不確実性などがあるが、これらを十分に比較検討し、将来の各時代断面での、また国際的な面での、妥当なミックスと地域別アロケーションを考えていくという姿勢が望まれる。ただし、その際の論理についてはまだ多くの議論の余地があると思われる。

今後における途上国の経済発展、人口問題、地球環境問題、新エネルギーの実用規模の見通し、などを考慮すれば、原子力開発利用の一時的なスローダウンはあっても、世界の大勢は原子力利用に進むという基本認識が必要である。

長期的にみて、二酸化炭素や放射性廃棄物の増加による地球環境への影響が懸念されている。と同時に、石油・天然ガスの枯渇傾向に伴うエネルギー供給力不足への心配も指摘されている。長期間にわたる有害環境からのリスクも、エネルギー等の欠乏によるリスクも、共に大きな問題であるとの認識が重要である。今後の科学技術の進歩により、予想もしなかった新エネルギー源開発の可能性や、有害物質等の無害化技術の確立の可能性もある。しかし、現実の政策においては、それらへの期待は最も控え目でなければならない。

わが国の原子力発電の将来見通しについては、政府目標として掲げられた原子力発電規模の実現性を確認することが必要である。目標達成にとって、目標とする電源構成に至る火力と原子力の建設比率を指針として電源開発を進めることもひとつの方法であろう。また、原子力発電の理解の促進にとっては、生活大国5ケ年計画、二酸化炭素排出抑制目標などを支えるための原子力発電の役割について、広く一般市民に明示していくことが必要である。

原子力開発全般にわたり柔軟性を高めておくことも、最近のような流動的な時代には必要なことである。その場合、具体的な開発利用計画の展開に伴って現存する巨大な慣性力や、将来的な長い必要準備期間などと、柔軟性確保とをどのように両立させるかが大きな課題である。

従来にも増して、内外に理解される原子力開発利用の姿を一層明確に示すことが求められている。なぜ原子力なのか、高速増殖炉なのか、プルサーマルなのかなど、どこまでも分かりやすく説明することが必要である。また、生活の場でエネルギーを考え、生活と原子力との係わりを十分説明していくことが必要である。生活に直結した原子力と受け止められれば、一般市民に対して強い説得性を持つことになろう。

今後長期的には、原子力と人類社会及び自然環境との調和・共存を求める方向に向かうであろう。したがって、原子力開発利用長期計画においては、国際性のある原子力政策の展開、透明性の配慮、社会的安心感の醸成などはもとより、社会や環境との共生意識の醸成についても、力を入れて検討していくことが望まれる。

(2) 原子力開発利用の必要性と意義について

原子力は、エネルギー利用、RI・放射線利用などの直接的利用の面はもとより、科学技術フロンティアの開拓、高度技術産業の振興、地域の総合的発展などにとっても大きな役割を果たしつつあり、その必要性についての理解は次第に深まってきている。

原子力は、持続的な経済発展、適切なエネルギー需給、地球環境の保全のすべてを同時に可能にすることのできる最有力のエネルギー源として、国際的にもアピールされている。二度にわたる石油危機の中、原子力開発を進めてきた結果、先の湾岸戦争の時でも電力供給不安はなかったし、平常時においても供給信頼性・安定性・環境性に優れた電源として評価されている。

今後は資源の有限性と地球環境問題に、より大きな焦点を当てながら原子力の必要性と意義を一層明らかにしていくことが重要であろう。

しかし、このような必要性の認識に基づいて原子力が安心して受け入れられるためには、原子力平和利用に伴うリスク、すなわち原子力施設事故による放射線影響と環境汚染のリスク、放射性廃棄物による環境汚染リスク、さらには核拡散に対するリスクの問題が徹底的に検討されるとともに、それらのリスクが許容されるレベル以下であることの十分な理解が得られることが前提となる。

旧ソ連における原子炉事故・核燃料施設事故・原子炉等の海洋投棄の事例などを別にすれば、原子力は技術的には現在、他のエネルギー・システム、他の社会システム等のリスクと比較しても十分信頼でき、十分安全なレベルに達しているものと専門家は判断している。むしろ問題は管理の体制・システムにあるといえる。

リスクの低減に関しては今後、技術的にはさらに進歩が期待できるが、管理体制についても逐次改善されていかねばならない。ただし、その管理体制は社会に対して十分に開かれた、透明性とアクセス性の高いものでなければならない。

要約すれば、原子力はエネルギー・放射線利用、科学技術、社会経済、文化を広く包含した総合的な新パラダイムであると認識される。今後、情報とミクロ世界を基幹とするハイテク、人間学、社会学、環境論などと重なり合いながら展開されると思われる。もろもろの可能性があり、潜在リスクもある。時間をかけ、適切にコントロールしながら活用することで、多くの可能性を実現していくことに意義があると考える。

(3) 軽水炉の安全確保と高度化について

原子力開発の議論はすべて安全性に帰着するといっても過言ではない。長期計画の検討にあたっても、安全性はすべての問題にわたっての基本的視点として認識することが必要である。とくに、軽水炉の長期化は必須であり、基数の増大を考え合わせると、安全性のさらなる向上のため、巾広く関連の安全研究を進めることが肝要である。

既設プラントの予防保全、経年劣化対策、長寿命化、廃止措置を含めた放射性廃棄物対策などの検討を深めること、またシビアアクシデント・マネージメントの対策についても、世界の大勢に遅れることなく、所要の研究と方策の検討が必要である。

安全性の一層の向上という定量的視点を欠いた目標ではなく、合意された安全目標を効果的なリスク管理により達成する観点から、ライフサイクル全般にわたり、限られた人と時間と資金を効果的に活用する枠組みを用意し、提示していくことが必要である。

安全目標を達成し、その状態を維持していくには絶えざる安全への努力が求められる。さらに、安全目標は時代とともに高められてよい。他の分野のシステムも含めて、それらのいわば究極の安全を目指す科学的研究に革新的視点から取り組むべきである。

原子力の安全のクレディビリティは、当事者・規制側・公衆のそれぞれのクレディビリティをもって成立するものであり、どれが欠けても十分とはいえない。

原子力安全はグローバルな課題であり、原子力の規格・基準のグローバリゼーション(世界的統合化)の動きが強まっている。国際安全条約の検討も始まっている。わが国も、これらの分野で積極的な貢献をしていくことが必要である。

原子力施設等の評価上の潜在リスクについては、シビアアクシデント・マネージメント対策の推進と、受動的安全概念を極力取り入れた次世代炉の開発の両面から、さらなる低減に努めることが望まれる。

人に優しい次世代の原子力システムとはどのようなコンセプトになるか、いろいろな角度から研究を加速的に進めていくことが必要である。

(4) 放射性廃棄物の処理処分について

高レベル放射性廃棄物の処理処分は最重要課題の一つであり、一般市民の目に見える形の施策を積極的に推進する必要がある。安全管理・地域との共生を含む立法措置などを講じて、地域社会の人達のよりどころを明らかにすることが望まれる。深地層の研究施設についても早期の実現が必要である。

地層処分が行なわれた地上の部分を一般に解放して、人が集るような公園にすることもよいのではないか。

超ウラン元素の群分離・消滅処理技術は、高レベル放射性廃棄物を減らす上でも、資源の有効利用を図る上でも、長期的な研究に値する重要な技術である。

(5) 核燃料リサイクルと高速増殖炉について

わが国は、資源の有効利用、エネルギー・セキュリティの確保、放射性廃棄物の適切な処理の観点から、軽水炉、再処理、高速増殖炉という路線を進めてきた。世界のエネルギー安定供給に寄与するためにも、この路線は今後とも不変である。プルトニウムの平和利用は資源小国、技術立国のわが国にとってだけでなく、長期的な世界のエネルギー需給・地球環境保全にとっても、極めて重要である。

しかし、このようなわが国の核燃料リサイクル政策は、国際的にも十分理解されねばならず、その論理性と透明性をさらに高めていく努力が要求されている。

核燃料リサイクル全体については、理論とシナリオ、時間的な整合性と弾力性、及び実現性が重要となる。

わが国の高速増殖炉開発は、広く人類社会のために役立てるという発想に立って、わが国の最大限の力を注ぐことはもとよりとして、国際的な技術と資金の協力を得ながら開発していくことが考えられる。実証炉建設の早期具体化は重要な課題であり、民間の最大限の努力と国の協力・支援ならびに国際協力の下に、着実に推進する必要がある。

軽水炉から高速増殖炉に至る基本路線を進めていくにあたり、内外の諸情勢に十分配慮しながら、柔軟性を持った計画の下に進めていくこと、具体的には増殖技術に限定しない高速炉の開発計画を、長期計画の中に位置付けることが必要である。放射性物質の消滅を目的に付加し、高速炉開発を燃料サイクル全体の中で整合性をもって位

置付けることが重要である。

新型転換炉はプルトニウムの柔軟な利用に適するので、軽水炉から高速増殖炉への路線を補完するものであり、継続的な開発努力が必要である。

(このほか、プルトニウムの利用と管理に関しても多くの意見が見られるが、「セッション2」でこの問題が集中的に取り上げられると思われるので割愛する。)

(6) その他

原子力研究開発のフロンティアの推進に関しては、①わが国として純粋の基礎研究の分野で相応の国際貢献を果たし得るよう、基盤整備を進めることが最重要課題の一つであること、②大学の原子力研究設備の老朽化対策が急がれること、③原子力安全研究等を進める上での戦略的研究が必要であること、④高温ガス炉の位置付けを明確にし、技術開発を進めていくことの重要性、⑤ITERへの積極的参加と、他の方式の核融合研究に対するビジョン検討の重要性、⑥さらに多岐にわたる国際協力研究を計画し推進していくことの重要性、などが指摘されている。

国際化とグローバリゼーションの中でのわが国の原子力のあり方に関しては、①これからは原子力平和利用の技術を高度化していく役割を、世界に率先して担うべきこと、②アジア地域での原子力開発の中心的役割を果たしていくこと、③非核兵器国として再処理を行なう立場を踏まえつつ、核不拡散体制の確立に向けて積極的な提言や協力を進めること、などが指摘されている。(核不拡散の問題に関しては多くの意見があるが、「セッション5」と重複するので割愛する。)

原子力施設の立地と地域振興に関しては、①地域の総合開発を支援し、地域の原子力として根付くことが肝要、②制度疲労がないかなど、フレッシュな目で見直すことも重要、などが指摘されている。地域社会に融和した原子力発電所のあり方の例として、熱供給、サイトの部分的公園化などの提案も出されている。

原子力への理解の促進に関しては、①学校教育のカリキュラムにエネルギー、環境、原子力を適切に盛り込むこと、②情報公開をさらに進めること、③マスメディアによる正確な報道に期待すること、などの重要性が指摘されている。

4. おわりに

以上、「セッション1」での討論のご参考までに、原子力開発利用長期計画の改訂にあたっての重要課題の広がりと、それらを巡る意見等のごく概要をご紹介申上げた次第である。ご意見をたまわった各位に対し、また当セッションにご参加下さった皆様に対して、紙面をお借りして厚くお礼申し上げます。

DIRECTION ABOUT JAPAN'S NUCLEAR FUTURE

by Colette LEWINER
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After fifty years of existence nuclear energy achieved a tremendous development. By the end of 1991, 420 nuclear power plants were in service in 25 countries in the world, representing 17 % of the electricity production and 76 nuclear power plants were under construction.

Fourteen countries rely on nuclear energy to meet more than 25 % of their electricity needs. Among these countries, 11 are European, France comes first with 75 % of nuclear electricity generated in the world. The three other countries belong to your part of the world : Korea (47 %), Taiwan (38 %) and Japan (27 %). (See table 1). For EEC only, the nuclear electricity share is 30 %.

If we consider reactors'life experience, by December 31st, 1991, Western Europe totalized 2 300 years–reactors without accident, versus 1 800 years for the United States of America.

TO BE AT A TURNING POINT

Despite these achievements, nuclear energy seems to be at a turning point in its history or at least be a debatable question. This situation should not be contemplated from a negative point of view but must be considered as the proper time to turn challenges into opportunities and to do it not on only a national basis but also on an international level.

Out of any economic reasons, nuclear industry development is in keeping within a general energy policy cycle. After a development period (up to 1975), nuclear energy knew an investing period corresponding to the era of nuclear power plant construction (1975 – 1990). In this respect, France played an important part in this investing period. As nuclear power plants are built to generate electricity for at least 30 years and as their lifetime could be extended to 40 years, we are now facing, in Western Europe, a period in which new investments are made to meet the increase in electricity demand. In some Eastern European countries, the completion of nuclear plants under construction or new investments are also related to the shutdown of polluting fossil fuel fired plants. However, the next large investing period in Europe for nuclear should start again around 2010 – 2015 when the present plants will have to be replaced. We must get ready for it.

LONG TERM VIEW

Establishment of Nuclear as an energy source

Nuclear energy benefits from essential and modern qualities as an energy source as the world energy demand will keep on growing.

The qualities of nuclear energy are its winning cards, I mean competitiveness and gentleness towards the environment.

. *Nuclear Competitiveness*
It has been demonstrated in many European countries (France, Finland, Sweden) on a fair comparison basis with other energy sources. Furthermore nuclear kWh cost includes externalities such as provision for dismantling and waste disposal which is not the case for other energy sources.

. *Nuclear Gentleness to the Environment*
Nuclear is clean, since it doesn't emit any carbon dioxyde (CO_2), the principal agent of the greenhouse effect which is a human made phenomenon when related to energy production.

It has been estimated that without nuclear energy, the emission of CO_2 due to electricity generation in the EEC would be 2/3 higher than presently, and nuclear power plants reduce CO_2 fumes by 700 million tons per year in the EEC. The future of nuclear energy can therefore increase or decrease greenhouse gas emissions. According to ENS calculations, CO_2 output due to the entire European electricity sector would rise from the present 2 200 millions tons to 5 250 tons per year (i.e. x 2,5) if nuclear power were phased out in Europe by 2 010 and replaced coal or gas-fired power station.

In contrast, if Europe doubled its nuclear generating capacity over the next 20 years by 2 010, the CO_2 output from the electricity sector (including the whole CIS) could be cut from 2 200 millions (present level) to 1 420 million tons (i.e. 55 %) (see table 2).

. *Energy and development*
The growing demand for energy is the prerequisite for development and development is even more an absolute necessity for developping countries than for developped countries. According to the present estimates, the world population should reach 9 billion people in 50 years from now. If we make the assumption that the standard of life of this population is half that of the United States of America and that conservation measures lead to an electricity growth only equivalent to half of the GNP's growth, the electricity consumption should be three times as important as today. Energy production using mainly fossil fuels might be one of the major endangering factors of our planet if we don't care.

Next generation reactors

Nuclear cooperation is a reality especially in the field of research and future reactors.
Neither the national industrials nor national utilities can any longer work separately on tomorrow's reactors. Even if the Western reactors already achieve a very high level of safety, it is recognized that there is room for simplification in the design, operation and maintenance of the LWR reactors. In the future, risks will be implicitely taken into account with appropriate methods at the design stage both for LWR's and Fast Breeder Reactors. European utilities are getting organized to meet the challenge of the future development of nuclear energy by joining in the European Utilities Requirements (EUR) association. On another hand the French and German utilities have undertaken a cooperation together with SIEMENS and FRAMATOME and their daughter company NPI for the development of the European Pressurized Reactors.

International cooperation with similar US and Japanese programs and projects are also of prime importance since nuclear actors are convinced of the interest and necessity of a greater multinational dimension enabling them to sell the same product all over the world.

Nuclear site

Nuclear power plants and nuclear facilities are generally well accepted by local people for whom they are sources of economic development and employment. Controversy is often if not always the fact of people outside the vicinity.

Beyond the general information given during the site selection proceedings, efforts are locally made in favour of a total transparency on the operation of the power plant.

A country like France has not encountered any major difficulties in finding and selecting sites, the geographical conditions were favourable. A larger number of sites have been engaged and extension are still available on four sites for new units (Flamanville, St Alban, Penly, Civaux). New sites are also under prospection.

Dismantling is another aspect of nuclear site policy. It will be the next century business but, provisions have already been made and some dismantling operations engaged.

The nuclear operators know how to dismantle, they have the technology for it and principles and rules have been adopted on an international basis. Beyond technological aspects, dismantling will certainly depend on the necessity to recover site for use.

COMPREHENSIVE DEVELOPMENT STRATEGY BASED ON A LONG TERM OUTLOOK

A 1991 survey on French public opinion and nuclear energy reveals that the most important arguments in favour of nuclear are French energetic independance (37 %), French economic development (21 %) and kWh cost (19 %).

If 57 % agree with the French energy policy, safety (a fear of another Chernobyl accident) and radwaste issues are the main arguments (40 %) for nuclear energy opponents.

Energetic independance, safety and radwaste are certainly not issues specific to French public opinion they are worldwidely shared issues.

. ***Energetic independance***

From the start, the energetic independance was the main reason for developping a nuclear program.
Today, France and other European countries reprocess their used fuels. France and Germany recycle the reprocessed uranium and plutonium in their LWRs. The Melox plant under construction will be in operation in 1995 with a capacity of 130 t/year of Mixed oxide fuel and EDF has decided to feed its power plants with Mox fuel. This is an important contribution to energetic independance and natural commodity savings. Mox fuels save around 20 % of the natural uranium and 15 % of SWU's needs.

Fast Breeders Reactors (FBRs) should also generate electricity in the future and contribute to uranium savings. As an unlimited energy supplier, we do not urgently need FBRs but the present context might not prevail for ever.

As an adjustment of the quality of plutonium used in mixed oxide fuel for recycling in LWRs, there is already room for FBRs.

As an incinerator for actinides, in particular from nuclear weapon dismantling, there is an urgent need.

Cooperation continues at the European level on Fast Breeders Reactors that should be needed within 20 years from now to insure a sustainable development of nuclear energy if nuclear energy plays an important role in the energy mix, which I personally believe. This cooperation should develop beyond Europe.

. ***Safety concerns***

The TMI incident and more recently the Chernobyl accident played an undisputable part in the stepback of nuclear energy in some European countries (Italy, Sweden, Spain) and in the worldwide concern for safety in public opinion. Other countries are engaged in an ambitious and steady nuclear program such as France in which 75 % of the electricity generated is provided by nuclear energy and Japan. In France and more generally in Western Europe, safe operation of nuclear plants and nuclear facilities, permanent enhancement of a safety culture, transparency towards the public are key factors of success. Moreover important initiatives to enhance safety in central and eastern European countries are promoted, either or an international level within WANO or on an European level with the twinning Programs or on a national basis as it is the case with EDF that operates a twinning between the Bugey and Kozloduy in Bulgaria.

. ***Radwaste***

Nuclear is also clean as far as waste are concerned. Efficient technologies have been developped and responsible principles making consistent use of concentration and confinement principles instead of dilution and dispersion have been adopted.

If we consider nuclear electricity generation in France, radioactive waste represent 1 kg/inhabitant per year out of which 20 gr are fission products, to be compared to 2 500 kg of industrial wastes/year/inhabitant.

Moreover reprocessing used fuels allows to separate uranium and plutonium from fission products and thus the wastes are conditionning in an appropriate way regarding their future disposal. For example, in France, reprocessing generates 1 400 l of highly radioactive waste per ton of fuel against 2 000 l/ton in the case of direct storage. These performances will be improved.

Promotion of fundamental science and technology

Nuclear energy is young. However the enthusiastic R and D effort that sprang fifty years ago, when the first industrial applications were developped, seems to be on the decline when R & D should be needed to reinforce the nuclear option in the future.

The main objective of Nuclear R & D being to improve safety, reliability and economics. To attract the new generation, to restore faith in Science and Technology for a better living world should certainly be a favourable argument for Nuclear.

. ***Improve Safety***

It means to bring a better understanding of physical phenomena, allowing the designer to fulfill more readily the requirements of demonstrasting the safety.

The main target being to limit effectively the immediate risk as well as the long-term consequences.

. ***Reliability***

It deals with plant life extension for which it is necessary to develop predictive models on the effect of irradiation, to develop monitoring and study stress corrosion cracking of certain alloys.

. ***Economics***

Competitiveness of nuclear energy is one of its winning cars, R & D has a part to play to maintain this competitiveness both for the design of the new plants and the operation and maintenance of the actual plants. Competitiveness must be also achieved all along the fuel cycle. More accurate information on and better understanding of fuel behavour facilitate easier operation of the nuclear power plant as operational margins are established on a firmer basis.

FROM AN INTERNATIONAL POINT OF VIEW

The existence of a comprehensive and steady nuclear program in Japan, Korea and Taiwan is of paramount importance for the world nuclear community and especially in Europe. This is the evidence of nuclear future.

In a mass media era, to behave like a community and to benefit from information networks is essential. This also true for the nuclear industry. The Nuclear Community exists. Some examples prove it : the international exchange of information through WANO or under European initiatives such as the Active Twinning Program of nuclear power plants, the international cooperation in the field of future reactors.

ENS is another form of this community. It is the information network dedicated to Europe but open to worldwide exchange and cooperation. As the nuclear European Community, ENS represent more than 22 000 engineers and scientists from 25 European countries to whom it provides a platform to exchange information by different means :
- topical meetings,
- ENC's conferences every four years,
- Students'exchange program,

ENS is also an information network :

- Platform papers are produced on major nuclear issues ;

- Nuclear Europe Worldscan (NEW), the European Nuclear magazine, the most important and most circulated nuclear paper in the world

- Every year, ENS organizes Pime (Public Information material exchange), the annual worlwide Nuclear PR's meeting ;

- In 1990, ENS launched Nucnet, a worldwide fax service which started operating in 1991. By mid 1992, Nucnet counted 29 members and associates from all parts of the world.

  The aim with Nucnet was to circulate accurate, factual, objective news about nuclear energy – positive and negative – as well as background in order to help the media and public to join a balanced picture of nuclear power.

  Nucnet is distributed to news agency and information people in affiliated countries.

OBTAINING UNDERSTANDING AND RELIANCE BY THE PEOPLE

Public opinion is certainly the real challenge for nuclear.

It is of prime importance for the future development of nuclear energy to be recognized by politicians and by the public as part of the energy mix needed for a sustainable worldwide development.

This should be obtained through an appropriate and transparent multi-target communication leading people to feel they need nuclear energy for the sustainable economic development, for the preservation of our planet, for everyday life confort, ... The adoption of the International

Nuclear Event Scale (INES) from IAEA is of paramount importance in the transparency of operation of nuclear facilities.

Communication is easy to say, but not so easy to do. International cooperation is essential in this field, even if action must be adapted to the national context and country sensibility and experience.

Exchanges on communication initiatives should be more developped to benefit from their experience. PIME, the annual Public Relation Officers meeting organized by ENS is a first step in this direction.

NUCLEAR FUTURE IS IN OUR HANDS

Nuclear industry is conscious of its winning cards as well as of the challenges to be faced. They are basically the same all over the world. Therefore we must keep on building a worldwide nuclear community to better approach safety problems and communication with the public and the opinion leaders.

Table 1

Countries in which nuclear power contributes to more than 25 % to electricity generation

(1991) AIEA figures

Country	Part of nuclear power
France	73 %
Belgium	60 %
Sweden	52 %
Hungary	48 %
South Korea	47 %
Switzerland	40 %
Taiwan	38 %
Spain	36 %
Bulgaria	34 %
Finland	33 %
Czechoslovakia	29 %
Germany	28 %
Japan	27 %
Slovenia	25 %

Table 2 : **Carbon dioxide releases for total Europe for electricity sector in million tons per year.**

Scénario	1988	2000	2010
Actual	2200	–	–
Without nuclear	2900	4100	5250
Official plans	–	3000	3240
Doubling the nuclear generating capacity	–	–	1420

Summary of Remarks by

E.C. Brolin
Acting Assistant Secretary for Nuclear Energy
Deputy Assistant Secretary for Civilian Reactor Development
U.S. Department of Energy

Ladies and gentlemen, I am happy to be here today representing the United States Department of Energy at the 26th JAIF annual conference.

Mr. Mori has invited us to give our views with regard to the future of Japan's nuclear energy program, which is in the process of review here.

I appreciate this kind offer, but I believe it would be somewhat presumptuous of me to offer specific advice regarding the Japanese direction in nuclear energy.

Instead, I hope it will be helpful to provide a brief statement of the revised U.S. nuclear power research and development program.

I begin by noting that energy choices by each of our countries must primarily reflect our particular circumstances as regards natural resources.

For example, the United States has considerable fossil fuel reserves, particularly coal and natural gas, as well as uranium. Other countries are not so fortunate in these areas and have to make adjustments accordingly.

Despite our abundant fossil fuel reserves, 22% of our electricity, or 99,000 Megawatts, comes from nuclear energy. In many of our states, nuclear power provides more than 40% of the electrical power. We have 109 operating power reactors, 26% of the world's total.

Nuclear power will be needed to meet future demand.

Nuclear power offers many environmental advantages, including no toxic air emissions and no greenhouse gas emissions, which are also important to us.

In other words, we need nuclear power for the foreseeable future as an energy supply option.

Recognition of this is reflected in the Administration's Fiscal Year 1994 budget proposal for nuclear power research and development. The budget proposal:

- o Continues, unchanged, the advanced light water reactor research and development program, which provides near-term benefit in making available the next generation of light water reactors in our country

- o Supports actinide recycle research using pyroprocessing, which has the potential of a major breakthrough in nuclear waste management. A feasibility demonstration is planned by the end of Fiscal Year 1997.

- o Preserves international agreements with respect to collaboration on the pyroprocessing technique for actinide recycle

The proposed budget also reflects both a change in priorities as compared to the previous administration and budget stringencies. Thus the budget proposal:

- o Cancels the modular high temperature gas-cooled reactor program

- o Cancels the advanced liquid metal reactor design activity

- o Closes all reactor test facilities at Argonne-West, in Idaho, except for the Fuel Cycle Facility and Analytical Chemistry laboratory

The advanced light water reactor program remains unchanged from the current Fiscal Year 1993 program and is fully funded at $57.8 million as the government's share. The program is cost-shared more than 50-50 with industry and consists of the following program elements:

- o Design certification of four designs by the Nuclear Regulatory Commission

- o Commercial standardization for two lead designs

- o Completion of the early site approval process

- o Demonstration of the license renewal process

It will make advanced light water reactors available for an order by the mid-1990's for operation around the turn of the century. This is the only technology that can be available in the near term.

The program supports extension of plant lifetime beyond the arbitrary 40-year license period, which reduces the need for replacement generating capacity in the near term.

The actinide recycle program research is continued because of the potential to contribute to the management of high-level radioactive waste in the long term.

As shown on the curve entitled, "Spent Fuel Buildup from Mix of Reactors on Once-through Fuel Cycle", the capacity of our first repository is fully committed by the time it is opened in 2012,

Thus there is a requirement for more repository capacity even if there are no U.S. nuclear power plants beyond those now operating, and that situation is unlikely, given the contribution which nuclear power makes to our generation mix.

The advantage of our pyroprocessing approach is that it potentially delays -- significantly -- the need for additional repository capacity.

It is also proliferation resistant.

Fundamentally, it has the potential to put to use a material, i.e., light water reactor spent fuel, that would otherwise be wasted.

The technical and economic feasibility demonstration is scheduled to be completed by Fiscal Year 1997.

In summary, although reduced from past years, our Fiscal Year 1994 program:

- o maintains the ability of the nuclear industry to deploy new plants by the mid-1990's and

- o maintains a nuclear waste management option using pyroprocessing which we believe has the potential to be more economical than currently available processes.

U.S. NUCLEAR ENERGY RESEARCH AND DEVELOPMENT PROGRAMS

E. C. Brolin
Deputy Assistant Secretary for Civilian Reactor Development
Office of Nuclear Energy

April 1993

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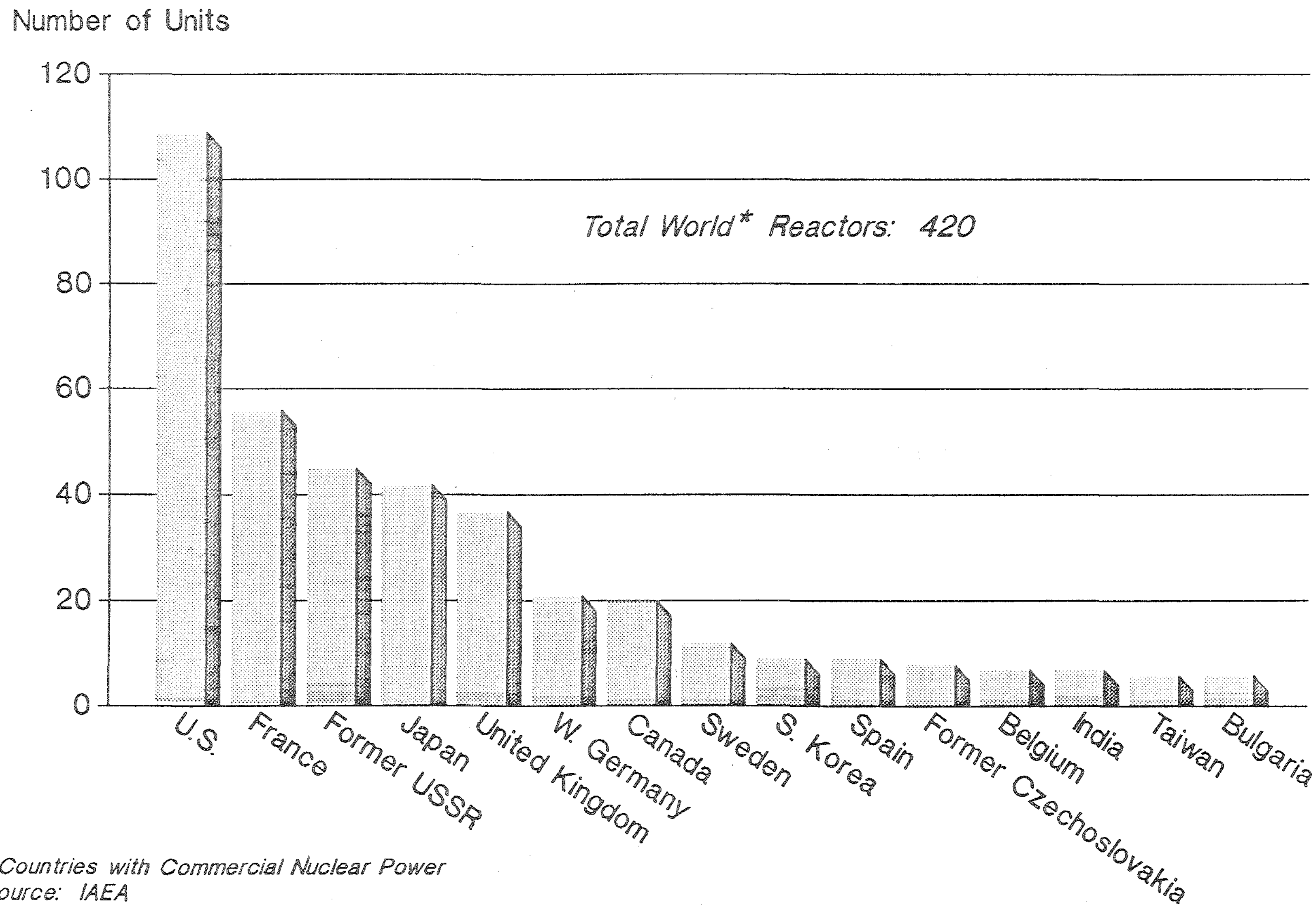
BACKGROUND

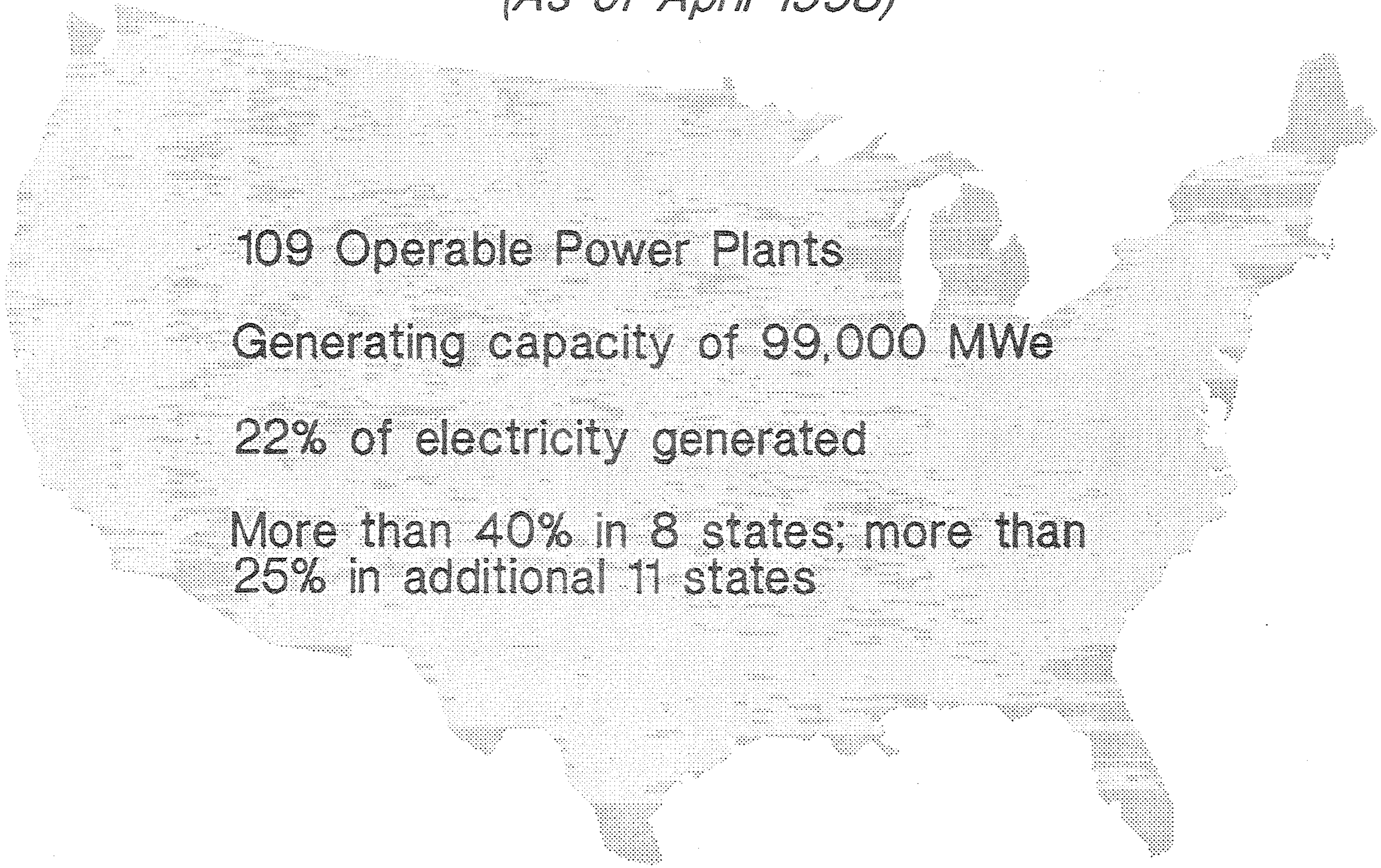
NUCLEAR POWER REACTORS IN OPERATION -- SELECTED COUNTRIES, 1991



* Countries with Commercial Nuclear Power
Source: IAEA

UNITED STATES NUCLEAR POWER IN PERSPECTIVE

(As of April 1993)



109 Operable Power Plants

Generating capacity of 99,000 MWe

22% of electricity generated

More than 40% in 8 states; more than 25% in additional 11 states

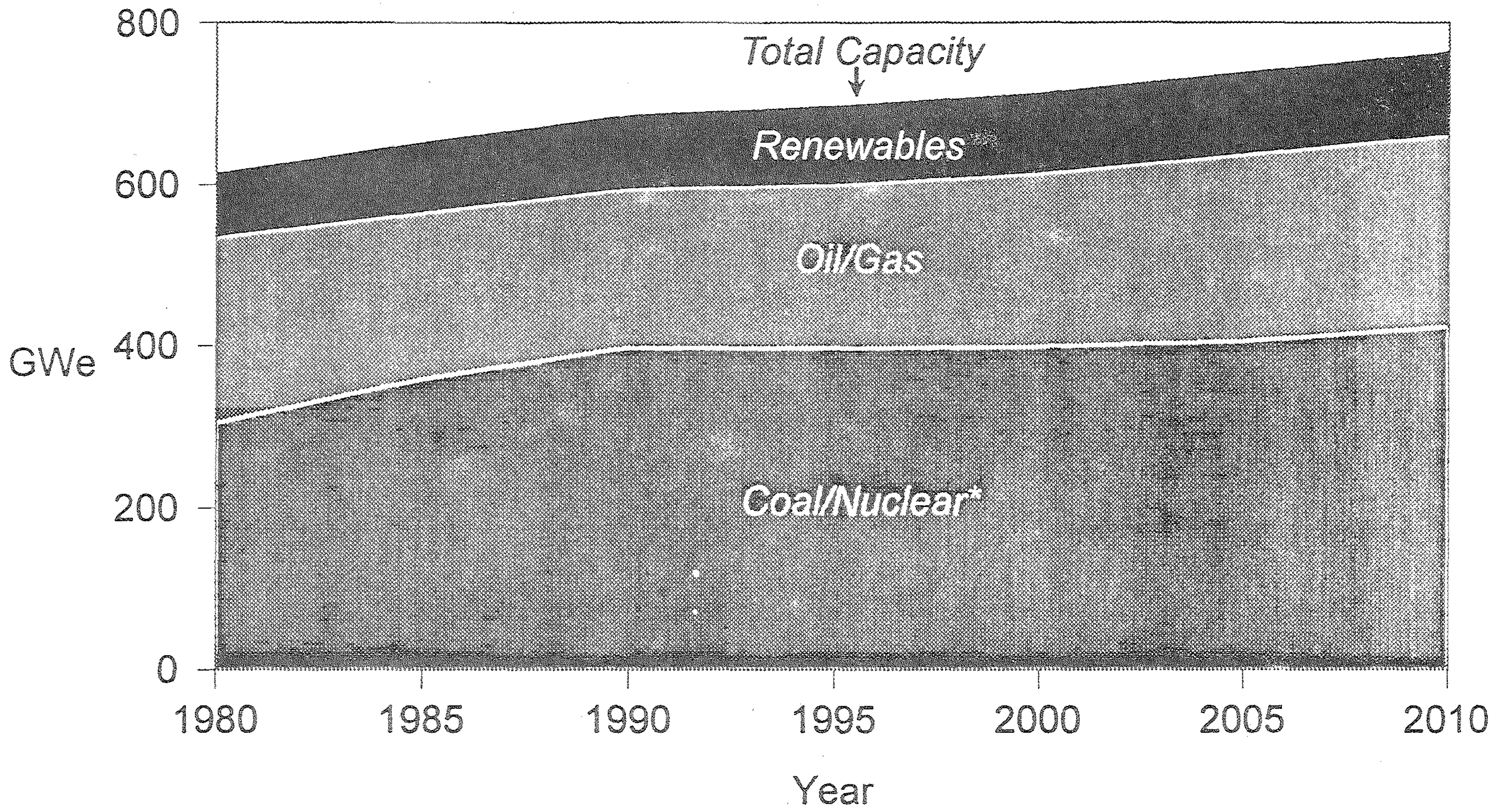
Source: EIA

WHY THE U.S. NEEDS NUCLEAR POWER

- Electricity demand must be met to ensure continued economic growth
- Conservation, renewables, and natural gas cannot meet total projected near and mid-term demand
- Coal and nuclear power will be needed to meet future electricity demand
- Nuclear power offers some environmental advantages:
    - No toxic air emissions
    - No greenhouse gas emissions

ELECTRICAL GENERATING CAPACITY

1980 - 2010



*Coal and nuclear provided 76% of electricity generated in 1990

Source: EIA

GOVERNMENT SUPPORT FOR NUCLEAR POWER

ADMINISTRATION'S BUDGET PROPOSAL FOR NUCLEAR POWER

Proposal

- Continue Light Water Reactor Program
- Complete actinide recycle research by FY 1997
- Cancel Advanced Reactor design activities
- Shutdown all facilities at Argonne-West except the Fuel Cycle Facility and the Analytical Laboratory

Benefits

- Preserves the Advanced Light Water Reactor Program
- Allows for potential major breakthrough in nuclear waste management
- Preserves international agreements
- Concentrates available funding on reactor program that is most likely to contribute to electricity supplies

DOE NUCLEAR ENERGY RESEARCH AND DEVELOPMENT

Advanced Light Water Reactor Program

THE LIGHT WATER REACTOR PROGRAM IS ORIENTED TO MEET NEAR-TERM GOALS

- No change from current program

- Make Advanced Light Water Reactors available to the marketplace for an order by the mid-1990s and operation around the turn of the century

  - ALWR is the only technology available in this time frame
  - Goal consistent with utility industry's strategic planning

- Enable currently operating nuclear plants to continue operation beyond their arbitrary 40-year license period

  - Reduces the need for replacement generating capacity starting in 2000

- Programs cost-shared with industry

PROGRAM ELEMENTS

- NRC design certification of evolutionary and passive plants
- Commercial standardization (first-of-a-kind engineering) for two lead designs recently selected
- Demonstration of NRC early site permit approval process
- Demonstration of NRC license renewal process
- FY 1994 proposed Federal funding is $57.8 million

DESIGN CERTIFICATION

Objective

- Demonstrate the NRC certification process (10 CFR 52)

Approach

- Industry designers are the applicants for NRC design approval
- DOE cost-shares (approximately 50/50) and oversees the process
- Four designs in the program:

  1300 MWe Evolutionary Plants

  - Advanced Boiling Water Reactor
  - System 80+ Pressurized Water Reactor

  600 MWe Passive Plants

  - AP-600 Pressurized Water Reactor
  - SBWR Boiling Water Reactor

ALWR CERTIFICATION SCHEDULES*

	Final Design Approval	*Design Certification*
ABWR	April 1994	1995
System 80+	April 1994	1995
AP600	November 1994	1996
SBWR	January 1995	1996

** Current estimated dates. NRC schedules to be updated during the next month.*

SAFETY COMPARISON

Evolutionary Plant

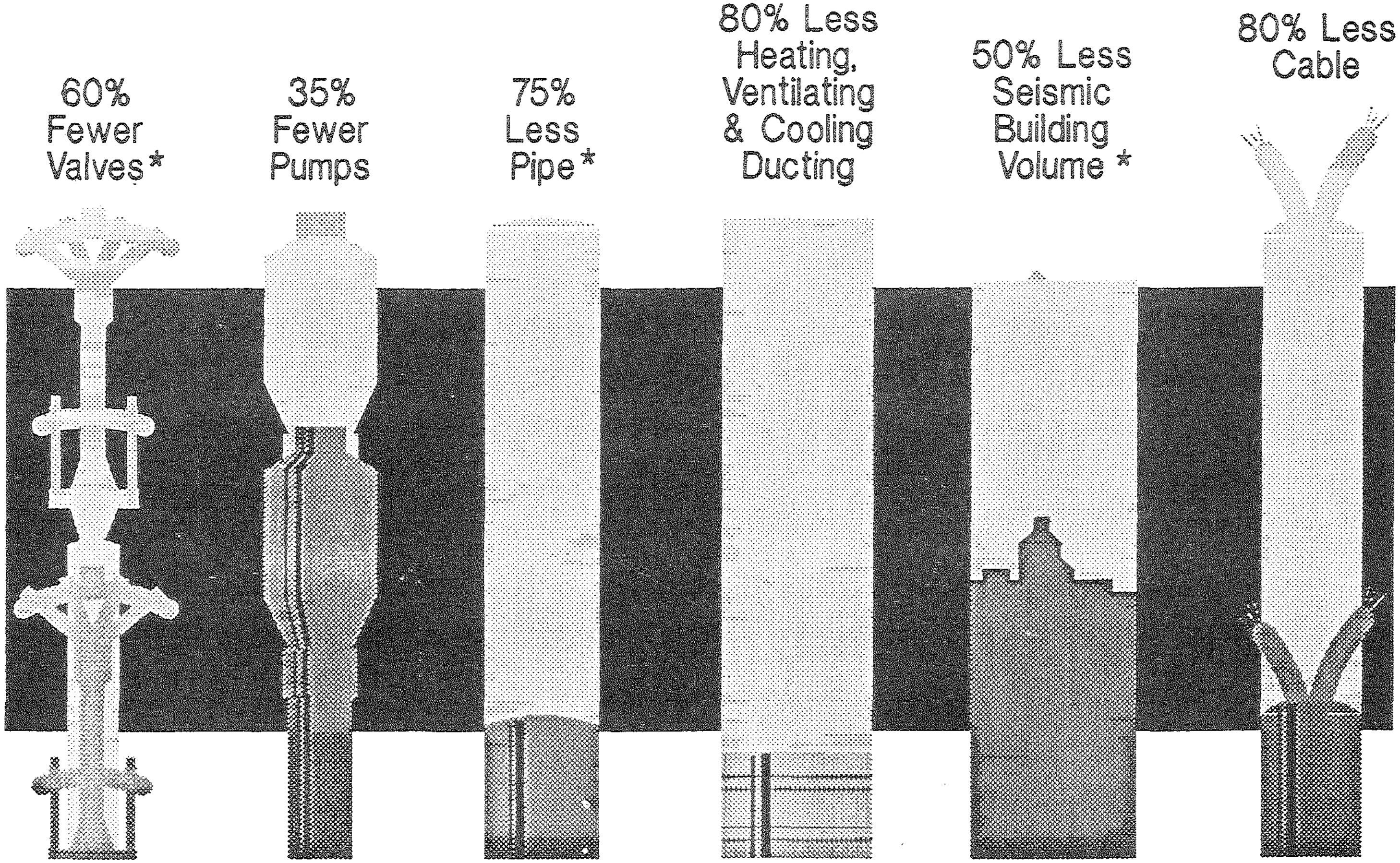
- Reduced core damage probability by a factor of ten from current plants
- Lower worker radiation exposure by a factor of two
- Increased thermal margins

SAFETY COMPARISON

Passive Plant

- Reduced core damage probability by a factor of one hundred from current plants
- Simplified design: number of systems and components reduced
- Increased safety margins relative to current plants
- Increased safety margins result in reduced dependence on immediate operator action (no operator action required for 72 hours)
- No auxiliary power supply required in accident conditions

REPRESENTATIVE REDUCTIONS FROM ALWR PASSIVE PLANTS



Simplification Contributes to Safety, Economy of Construction, and Operation

* *Nuclear Island*

COMMERCIAL STANDARDIZATION

Objective

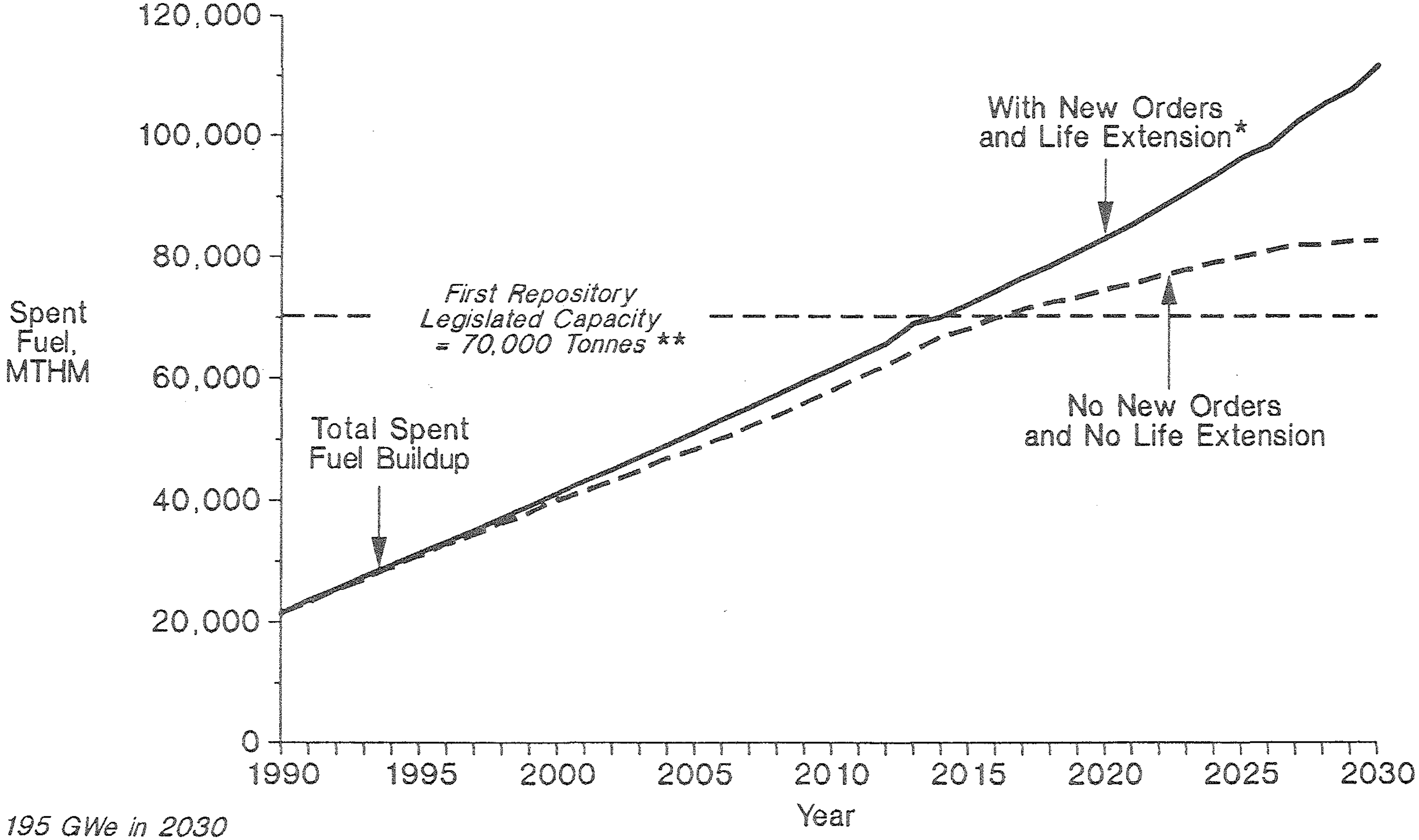
- Complete the design of one or more ALWRs to the point where design can serve as the basis for a family of standardized plants

Status

- Advanced Reactor Corporation is the U.S. industry organization for this program
- The Corporation selected two designs for the program
- Pledges were obtained for more than $100 million in industry cost-sharing for the program
- Contracts are being reviewed by the Department of Energy

Advanced Liquid Metal Reactor Actinide Recycle Program

SPENT FUEL BUILDUP FROM MIX OF REACTORS ON ONCE-THROUGH FUEL CYCLE



* *195 GWe in 2030*

** *This is the first repository legislated capacity applicable to both civilian and defense waste.*

ACTINIDE RECYCLE PROGRAM OBJECTIVE

- Evaluate technology that could contribute to long-term radioactive waste management system

- Benefits:

  - Potentially delays the need for additional repository capacity in the future
  - Diversion/proliferation - resistant fuel cycle
  - Provision of fuel from material that would otherwise be disposed

- Program to be completed by FY 1997

- Research supported by Administration

SUMMARY

- Maintains ability of nuclear industry to deploy new plants by mid-1990's
- Maintains research on actinide recycle using pyroprocessing technique

Honourable Chairman,
Ladies and gentlemen :

It gives me great honour to present to you some basic thoughts on the future of nuclear energy. Eventhough, I must humbly admit that it is really difficult for me to advance any comment on the long term nuclear energy program which is already very comprehensive and forward looking. The characteristics of the program manifest the high quality of the experts and expertise behind it.

However, allow me to start with the allegations by many observers that "since 1978 the role and contribution of nuclear in the world's energy supply scene have been slackening and this situation was also aggravated by the accidents at Three Mile Island and Chernobyl.

Furthermore, they remark that "nuclear energy is riskier and costlier than conventional alternatives".

We must agree with the first statement, but as scientists or technologists in the field it is hard for us to accept the second. However, we should admit that the perception of the general public is well represented by the second statement : that is "nuclear is riskier and costlier ...".

Right or wrong, both statements represent the hard social reality right now ! And this is the great challenge for us.

What are the root causes of the problem ?. We can intuitively answer that the reasons are more non-technological rather than technological ones.

From above considerations I would like to base my review and propose my comments on the nuclear energy program toward the 21^{st} century.

First, it is imperative to have a program to develop strategic links and alliances with social critics, environmentalists and politicians. With the objectives to develop and enhance mutual understanding, mutual trust, resolution of conflicts and finally to clear away the obstacles to the furtherance of nuclear energy use and new nuclear power plants construction. This program is supported in parallel with a more active, continuous, honest and visible information to the public in order to recapture the credibility of the mission of nuclear energy.

Second, I would like to mention a program on nuclear law and regulation with the main aim to clear away obstacles to certainty and finality of licensing; to avoid costly legal proceedings and unnecessary public hearings by intervenors. This is also in line with the program in NPP site strategy to facilitate the utilities in obtaining new sites.

Third, energy policy development program is very useful since nuclear energy should have a place within this policy. Nuclear policy research shall be an intergral part of the energy policy development.

Fourth, I would like to mention about development and application of management systems of nuclear facilities. This may be crucial to the success and safety of facility operation. Nuclear facilities (NPP's, nuclear fuel cycles facilities, irradiators etc.) are designed and constructed based on advanced technology with high standards. The potential weakness may come from the management system and culture in these facilities.

Fifth, nuclear program in the future needs supply of fresh blood of human power, who will come from universities. Hence, a program to support university education in nuclear science and technology and related subjects should be augmented.

Sixth, program in safety and radioactive waste management. Here, we expect to gain more information on human factors, comparative risks and benefits of various energy systems, severe accident management and how people will perceive them; clear cut radioactive waste disposal strategy but which is also open to future new requirements and development of technology.

Seventh, increase in efforts to support nuclear energy programs in basic human needs : health, medicine and environment. This is to be promoted for obvious reasons.

Eighth, nuclear cost reduction program. This program seems very prospective through design, technology, construction method, standardization and smooth licensing. The program is one of the keys to the revival of nuclear industry in the coming years.

Ninth, last but not least is program of international cooperation in the peaceful utilization of nuclear energy. Developing countries embarking on nuclear program need various kinds of assistance to enable them to manage the program safely, effectively and efficiently. Cooperation in the field of safety should also be intensified in order to enhance the standard of safety of operationg as well as future nuclear power plants and to avoid any future accident that will jeopardize the future of nuclear industry.

Honourable Chairman,
Ladies and gentlemen :

I would like to reiterate that my comments are based on above allegations and on my personal interests and concerns. Hence the validity is limited to above premises.

At last, allow me to thank you for your kind attention.

Commentator : I. SUBKI, Indonesia
14 April 1993

セッション２
今なぜプルトニウムか

＜基調講演＞

「わが国のプルトニウム利用政策について」

科学技術庁原子力局長
石田寛人

＜パネル討論＞

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菊池三郎

毎日新聞社科学部
瀬川至朗

「我が国のプルトニウム利用政策について」

科学技術庁原子力局長　石田　寛人

我が国は、１９５０年代半ばに原子力開発利用に着手した当初より、使用済燃料を再処理して得られるプルトニウム及びウランをリサイクルし、核燃料として利用することを目指した政策を一貫して取ってきている。この政策は、我が国の原子力開発利用の基本政策を示した原子力開発利用長期計画にも示されているところであります。この考え方は、我が国のようにウランについても、そのすべてを輸入に頼らざるを得ない国としては、長期的なエネルギーの安定供給の観点からプルトニウムを利用していくことが極めて重要との考えによるものであります。

昨年１１月から本年１月にかけて行われたフランスからのプルトニウム海上輸送、あるいは、我が国が開発を進めて参りました高速増殖原型炉「もんじゅ」が本年１０月には臨界を迎える予定であることなどを契機と致しまして、我が国のプルトニウム利用に関して、国内あるいは海外からも高い関心が寄せられております。この場をお借りしまして、我が国のプルトニウム利用政策の概要を述べさせていただき、我が国のプルトニウム利用についてご理解を賜ればと考えております。

まず第一に、我が国の原子力平和利用に対するコミットメントについてであります。

１９５５年に制定された我が国の原子力の開発利用の基本を定めた「原子力基本法」によって我が国の原子力活動はすべて平和利用に限られております。以来、今日まで、我が国は、この法律に従い原子力開発利用を厳格に平和目的に限定して進めてまいりました。言うまでもなく、原子力基本法は、我が国の原子力に対する取り組みの基本を定めたものであり、ここに掲げられた平和利用の理念は、唯一の被爆国である日本国民の継続的な強い決意を表すものであります。全発電電力量に占める原子力発電の比率が３０％近くになり、原子力開発利用の活動が広範に展開している今日、この原子力平和利用の理念をより

一層強固に堅持していくことが非常に重要であります。

また、国際的にも我が国は１９７６年、核兵器の不拡散に関する条約（ＮＰＴ）を批准して以来、その誠実な加盟国として、国内の全ての原子力活動について国際原子力機関（ＩＡＥＡ）の保障措置を積極的に受け入れております。我が国は原子力開発利用をいわば世界に対して「ガラス張り」の状態で行っております。これは、我が国の原子力利用に関して世界の不信を少しでも招くような行動をとることは、政治的には我が国の存在基盤を危うくするとともに、経済的には我が国のエネルギー供給の相当部分を担う原子力の平和利用推進を困難にし、結果として我が国の国家安全保障を著しく損なうものであることから、世界から少しでも疑念をもたれないようにするための我が国の決意のあらわれの一つであります。

また、我が国は、国際的に核不拡散体制の強化に向けてイニシャティブを発揮してきております。すなわち、国際原子力機関（ＩＡＥＡ）による核不拡散体制のなかで、「特別査察」、及びＩＡＥＡへの原子力施設の「設計情報の早期提出」及び原子力資機材等の輸出入に関する国際合意のため積極的に努力し、また、いわゆる汎用品の輸出規制及びその報告制度についても我が国の在ウィーン国際機関代表部がその事務局機能を果たすこととするなど、我が国は非核兵器国として厳に平和目的に限って原子力利用を進める立場から、これらの諸制度の創設に積極的に貢献してまいりました。

このように、我が国の核不拡散に対する強固な意志と実績は明白であると考えますが、我が国が今後本格的なプルトニウム平和利用を進めるに当たり、我が国の平和利用への強固なコミットメントについて国内外から一層の信頼が得られるよう引き続き努力していくことが重要であると考えます。

次に、我が国のプルトニウム利用政策についてご説明したいと思います。

我が国におけるプルトニウム利用の必要性及び利用に関する基本方針は、次に述べるとおりでありますが、今後とも、安全確保を大前提に、プルトニウム利用体系の確立に向けて、着実かつ段階的に政策を推進していく所存であります。

まず第１に、使用済燃料を再処理することによって回収されるプルトニウム

を利用することは、リサイクルしなければ、その全てが廃棄物となってしまうものの中から、有用なものを資源として再利用するものであり、このことは、資源と環境を大切にし、リサイクル社会の形成に貢献するものであります。このような資源の節約と再利用の努力は、我が国のような大量エネルギー消費国が積極的に取り組むべき重要な課題であります。

第2に、プルトニウムを利用することは、ウラン資源の有する潜在力を最大限に活用し、原子力を長期的に経済的かつ安定なエネルギー源とするものであります。使用済燃料から有用なものをリサイクルしていく努力は、資源小国、技術立国たる我が国として特に重視してきているものです。原子力は、その経済性が資源よりむしろ技術によって決められる点に特徴があります。プルトニウム利用の経済性も、研究開発の一層の推進、経験の蓄積、規模の段階的拡大等を通じ、将来的に向上していくことが期待されます。我が国がそのような技術開発に率先して取り組んでいくことは、長期的にみて、国際的にも有意義なものと考えます。

第3に、プルトニウム利用により、回収ウラン、プルトニウムなどの有用資源と廃棄物とを分離すれば、高レベル放射性廃棄物を安定な状態にしやすくなり、その結果、放射性廃棄物の管理をより適切なものとすることであります。

実際、使用済燃料を再処理した後に残る高レベル放射性廃棄物は、使用済燃料をそのまま廃棄物とする場合に比べて量が少なく安定な状態に固化しやすくなり、放射能の継続時間が相対的に短くなります。

第4に、核不拡散に関し国際的な疑念が生じないように、リサイクル計画の透明性に十分配慮し、我が国としては計画推進に必要な量以上のプルトニウムは保持しないことを原則とすることであります。我が国の具体的なプルトニウム利用計画については後ほど詳細にご説明いたします。

第5に、我が国がこれまでに蓄積した技術及び経験をもとに、ＩＡＥＡ保障措置の健全な発展と世界の核不拡散体制の強化に貢献することであります。また、プルトニウムを国際的に管理するという方針について国際的な検討が行われつつあります。このような検討についても我が国は積極的に参加することとしております。

次に我が国のプルトニウム平和利用計画についてご説明いたします。

一昨年8月、原子力委員会核燃料リサイクル専門部会は、２０１０年頃までのプルトニウムの利用計画を明らかにしており、我が国としては同計画に沿って今後のプルトニウム利用を推進していく考えであります。同部会は、いかなる場合であっても核不拡散の観点から国際的に疑念を生じることのないよう、プルトニウム利用計画の透明性に配慮するとともに、今後とも核不拡散に対する厳格な対応をとることが肝要であり、計画推進のために必要な量以上のプルトニウムを持たないことを原則とすることをうたっております。

専門部会は、２０１０年頃までのプルトニウム需要及び供給の累積（核分裂性プルトニウム量、以下同じ）の見通しを示しています。まず、プルトニウム需要として、高速炉については、実験炉「常陽」、原型炉「もんじゅ」及び実証炉及び実証炉以降のＦＢＲで２２トン～３３トン、新型転換炉については、原型炉「ふげん」及び実証炉で１０トン弱、９０年代半ば頃から段階的に利用を拡大していく軽水炉でのプルトニウム利用によって約５０トン、合計８０トンから９０トンのプルトニウムの需要を見込んでおります。一方、プルトニウム供給としては、現在は動燃事業団の東海再処理工場での回収と英仏への再処理委託に依存しておりますが、日本原燃（株）の六ケ所再処理工場建設計画が順調に進めば、来世紀はじめにはかなりの供給が我が国国内で可能となります。具体的な供給量としては、動燃東海再処理工場から約５トン、英仏への再処理委託によって約３０トン、２０００年頃に運転開始予定の青森県六ケ所村の再処理工場から約５０トン、合計８５トンのプルトニウムが２０１０年頃までの累積供給量となっております。

このように、我が国はプルトニウムの需給がバランスするように計画を進めていく方針であります。なお、この数字は２０１０年頃までの需給の累積値であり、また、各年度毎の需給も一定のバランスをとりつつ、計画を進めるものでありますので、ある時点で８５トンをため込むということではないという点に留意願いたいと思います。

我が国のプルトニウム平和利用は、高速増殖炉での利用を最終目標として推進しておりますが、同炉を発電体系の中で商業化するには、現在の原子力発電の主流である軽水炉に比べ、経済性等で競合し得るようになることが求められ、

なお、相当期間（３０～４０年）の着実な開発努力が必要とされています。幸い、実験炉「常陽」の過去１０年以上にわたる運転、そのためのＭＯＸ燃料製造等も順調に実施されてきており、これらの成果を活用し、本年秋の「もんじゅ」の臨界達成、その後の運転そして実証炉計画へと段階的、計画的に進めていくこととしております。なお、軽水炉におけるプルトニウム利用が、国内のプルトニウム利用に係る人材、技術、産業基盤等の整備に貢献し、このことが高速増殖炉開発にも役立ち、将来の高速増殖炉の実用化をより確かなものにすると考えています。

次に、解体核兵器から発生するプルトニウムの処理の問題と我が国との関係についてであります。

近年、核軍縮の進展と旧ソ連の崩壊により、核兵器の解体と解体後の核物質の処理又はその有効利用が課題となっております。解体核兵器から発生するプルトニウムの問題については、基本的には核兵器国自身の問題であると考えますが、私どもとしても解体によって生じる核物質が再び軍事に利用されないようにすることが極めて重要であると考えております。核兵器の解体により生じるプルトニウムを処理、処分するためには一定期間の貯蔵が必要となるでしょうが、そのまま置いておくだけでは核不拡散上、恒久的な解決策とはならないことから、しかるべき時期に二度と核兵器に使用されないように処理する必要があると考えます。この処理方法については技術的にいくつかのオプションが考えられますが、平和目的の原子炉燃料として燃焼させて電力エネルギーを得るのが、核不拡散の要件を満たす上でも効果的、建設的ではないかと考えられます。

いずれにしても、国際的な平和と安全保障を確保する観点から、核兵器解体により生ずるプルトニウムの確実かつ安全な処理について、特に、旧ソ連のプルトニウムについて、国際社会の納得が得られるような解決策が早期に見いだされることが重要であり、このための国際的な検討が加速されるべきであると考えます。我が国としてもそのために、関係各国、関係国際機関等との連携の下、国際的な努力に積極的に協力してまいる所存であります。従って、国際社会が、旧ソ連の核兵器解体から発生するプルトニウムについて、平和利用の原

子炉燃料として利用していく方向でコンセンサスを得ることとなれば、我が国が蓄積してきたプルトニウム取扱技術を活用し、協力していく用意があります。既に当庁においてはそのための技術的検討も進めております。私共は、この問題は我が国のプルトニウム利用計画とは明確に切り離し、世界の平和と安全の一層の促進に貢献するとの立場で対処していくべきものと認識しております。

最後に、プルトニウムを高速増殖炉において本格的利用するまでには、経済性、信頼性のある高速増殖炉の開発自体はもとより、プルトニウム燃料の国内加工体制の整備、プルトニウム燃料の再処理技術の開発など、まだまだ努力を要する課題が少なくありません。当面、新型転換炉や軽水炉によるプルトニウム利用は、それによってプルトニウムの取扱に係る人材、技術、産業基盤のかん養に資するものであり、私どもとしては、そのようなプロセスを経ながら一歩一歩着実にプルトニウム利用の本格化に向け努力してまいる所存であります。

また、我が国の原子力委員会は、概ね５年毎に実施している「原子力開発利用長期計画」の見直しを実施中であります。議論が進行中であり、新長期計画の策定時期を明確に申し上げられる状況にはありませんが、同長期計画の中で、将来の我が国のプルトニウム平和利用計画が国内外からよりよく理解されるものとなるよう、私共としても努力してまいりたいと考えております。

Plutonium Peaceful Utilization Policy

By Hiroto Ishida
Director general Atomic Energy Bureau
Science and Technology Agency

1.Introduction

Since the beginning of development and utilization program of nuclear energy in the mid-1950's, Japan has consistently taken the policy for recycling the plutonium and uranium recovered from reprocessing nuclear spent fuels nuclear fuel. This policy is based on the idea that it is extremely important use plutonium from the viewpoint of long-term stable energy supplies because Japan has to depend solely upon imported uranium.

The Japanese plutonium peaceful utilization holds attention of world these days. The following is outline of our country's plutonium utilization policy.

2.Deep Commitment to Peaceful Use of Atomic Energy

Based on "the Atomic Energy Basic Law" enacted in 1955 which basically stipulates the development and utilization of atomic energy,all nuclear activities in Japan are limited to peaceful purposes only.Internationally,as a faithful member of the Treaty on the Non-Proliferation of Nuclear Weapons(NPT),Japan accepts full-scope IAEA safeguards on all the domestic nuclear activities,and has taken the initiative in developing and strengthening the world nuclear non-proliferation regime.We believe that our country's firm will and achievement in nuclear non-proliferation are worldwide known.But we think it is very important for us to make strenuous efforts to win more confidence both from home and abroad in our country's deep commitment to the peaceful use of nuclear power.

3.Japanese Plutonium Utilization Policy

The necessity of plutonium use in Japan and basic policy regarding plutonium use are as follows.With securing safety as the precondition.We are determined to promote our policy steadily and by stages for establishing a plutonium utilization system in our country.

(1)To utilize plutonium recovered from reprocessing of spent fuels is to recycle useful material,all of which would otherwise become waste.This means to carefully handle the resources and human environment,and contributes the formation of a recycling society.

(2)To utilize the potential energy of uranium resource to the full,making nuclear energy an economical and stable energy source in a long-term perspective.It is by all means necessary for Japan which is scarce in natural resources to make an effort to recycle and re-use the useful substances in spent fuels.

(3)To make the radioactive waste management more appropriate by separating the useful substances from radioactive waste and making the high-level radioactive waste easier to be solidified into a stable form.

(4)It is our principle not to possess plutonium beyond the amount required to implement its nuclear fuel recycling programs so as to avoid any international doubt about our nuclear non-prolifera-tion policies,with due consideration would be given to transparency of nuclear fuel recycling program.

(5)Based on the techniques and experience accumulated so far,Japan will contribute to the sound development of IAEA safeguards and to strengthening the world nuclear non-proliferation regime.Furthermore our country will be active in participating in the international discussions on the international plutonium management.

4.Future Plutonium Utilization Program

In August,1991,Atomic Energy Commission Advisory Committee on Nuclear Fuel Recycling has clarified the plutonium utilization programs up to about 2010.Our country plans to promote its policies in accordance with this program.

This program shows the expected cumulative demand and supply of plutonium (fissile plutonium. The same shall apply hereinafter) up to about 2010.Plutonium in demand will be 22-23 tons required by the experimental reactor "Joyo",a prototype reactor "Monju" and a demonstration reactor,less than 10 tons by advanced thermal reactors a prototype reactor "Fugen" and a demonstration reactor and about 50,tons by light-water reactors,of which plutonium consumption will gradually be increased by stages,amounting to 80-90 tons.Regarding its supply,about 5 tons will be supplied from Tokai Reprocessing Plant,PNC,about 30 tons from the reprocessing services entrusted to U.K.and France,and about 50 tons from the Rokkasho reprocessing Plant,Aomori Pref.,amounting to about 85 tons.

Japan has policy to promote the program so that demand and supply of plutonium may be kept balanced.We would like to draw your attention to that these figures are the expected cumulative ones of demand and supply up to 2010.The demand and supply each year must also be balanced in carrying out the program.It should be noted that total 85 tons will not be stockpiled at a certain time point.

The plutonium use program in Japan is being promoted with its use in FBR as the final target.However more 30-40 years' steady effort is still necessary for commercializing FBR in the Japanese power generation system, since it is required for plutonium to become enough competitive in economic efficiency, etc. with LWRs which are now major source of nuclear power generation in Japan. Fortunately, the experimental fast reactor "Joyo" has been operated for these 10 years or more with fruitful experimental results, along with the manufacture of MOX fuel for it, etc. Utilizing these results, we'll have the "Monju" reach the criticality this autumn, and are decided to proceed to its operation and then the demonstration reactor program by stages and systematically.

5.Management of plutonium from dismantled nuclear weapons, and Japan

Since the recent progress in nuclear disarmament and collapse of the USSR, the dismantling nuclear weapons and management of the nuclear substances from them are an urgent task. Basically speaking, this task is the problem only with the nations that own these weapons, but it is essential that the nuclear substances produced from the dismantling will not be used again for military purposes. Through the plutonium coming from the dismantling weapons would necessarily have to be stored for a certain period, several technical options are available for its management thereafter. Of these options, it is considered the most effective and constructive way to burn it as the nuclear fuel for power generation in satisfying the nuclear non-proliferation requirements. Anyway it is important to find out the solution to the reliable and safe management of the plutonium produced from the dismantling of nuclear weapons, which solution must be supported by the international society from the viewpoint of securing the international peace and security. Our country is willing to cooperate with all others in the international efforts for it.

6. Conclusion

For the full-scale use of plutonium in fast breeder reactor, there still remain many matters to be solved, such as the development of an efficient and reliable fast breeder reactor itself, completion of the plutonium fuel processing system, development of the reprocessing techniques for plutonium fuel, etc. The present use of plutonium in ATRs and LWRs will be helpful for developing and cultivating the manpower, technologies and industrial infrastructure for plutonium treatment, and we are determined to steadily endeavor to achieve the full-scale use of plutonium step by step through such process.

午餐会
於　パシフィコ横浜　国際会議センター３階大会議室

通商産業大臣所感
通商産業大臣
森　喜朗

＜特別講演＞
「こころとことば」
慶應義塾大学教授
江藤　淳

セッション3

原子力技術―その信頼性とは・・・

＜問題提起＞

「原子力と信頼性」

東海大学教授

唐津　一

＜パネル討論＞

(財)鉄道総合技術研究所理事長

尾関　雅則

東京理科大学教授

菅野　文友

読売新聞社論説委員

中村　政雄

通商産業省資源エネルギー庁

公益事業部原子力発電安全管理課長

藤富　正晴

日本原子力研究所理事

松浦　祥次郎

コメンテーター

ウレンコ社社長

J．A．パーライト

セッション3

信頼性・保全性工学の立場から

１９９３年４月１５日

菅野　文友

１．大規模で複雑な現代のシステムの基本は、三つのＣすなわち、制御（Ｃｏｎｔｒｏｌ）と通信（Ｃｏｍｍｕｎｉｃａｔｉｏｎ）と情報処理（Ｃｏｍｐｕｔｉｎｇ）の三位一体化にある。三者の基本は、サイバネティクス（Ｃｙｂｅｒｎｅｔｉｃｓ）という点で共通である。そして、どれについても、信頼性（こわれにくさ）・保全性（なおしやすさ）及び両方を同時に考慮したアベイラビリティ（稼働率を拡張した言葉）の向上が基本課題である。

２．製品の故障率の単位は、当初の１０００時間当りの％から、１０^{6}時間当り、次にｆｉｔ（１０^{9}時間当り）、そして％・ｆｉｔ（１０^{11}時間当り）と減少している。つまり、当初の単位の百万（１０^{6}）分の一となっている。それに対して、ヒューマン・エラーつまり人間の誤りの率の単位は、千分の一ないし万分の一が、限界である。

３．ヒューマン・エラーの役割は、一般電気製品におけるヒューズのようなものと考え、センサーやインジケータといった前駆現象的な意味で活用すべきであろう。
或いは、何か異常があったら特定個所が不具合になるように、システムの状態監視保全機構を設定するということである。

４．一般に、システム製品の信頼性は、欠陥を回避するフォールト・アボインス（Ｆａｕｌｔ　Ａｖｏｉｄａｎｃｅ）と同時に、欠陥の影響を受けにくいフォールト・トレランス（Ｆａｕｌｔ　Ｔｏｌｅｒａｎｃｅ）の仕組みを考慮している。
すなわち、ディレイティング（Ｄｅｒａｔｉｎｇ）、並列冗長つまりジュアル（Ｄｕａｌ）、切替冗長つまりデュプレクス（Ｄｕｐｌｅｘ）、ｋ－ｏｕｔ－ｏｆ－ｎつまり多数決冗長、あるいは、その組合せなどを活用している。

５．要するに、保全性の問題を重視すると同時に、ヒューマン・エラーを冷静に取り扱い、「知らしむべし、倚らしむべからず」という方策で、全員参加の繰り返しと持続によるスパイラル・アップという、日本的品質管理の活用が、基本的行動である。
そして、「データに語らせ、データに聴く」態度の堅持を、忘れてはならない。

故障率	９９．９％無故障期間	９９．９９％無故障期間
１／１０^{5}時間	１．５ヶ月	４日
百万分の一％／時間	１２年間	１年２ヶ月間

セッション４
チェルノブイリ事故後７年を経た今は―何が真実か

＜基調講演＞
「チェルノブイリ事故後の影響評価」
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セッション４：「チェルノブイリ事故後７年を経た今は一何が真実か」

<基調講演>

「チェルノブイリ事故後の影響評価」

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【はじめに】

今回、私は、まず新聞や、ラジオ、テレビでも報道された国際チエルノブイリ計画の概要をご説明します。そしてその中で特に私の関わりました住民の健康への影響調査についてご紹介しながら、事故後7年目のチェルノブイリ事故の後影響の関する各国からの報告に触れてみたいと思います。

【国際チェルノブイリの概要】

1986年4月26日チェルノブイリ原子力発電所（第4号炉）で、大事故が発生しました。これは大量の放射性物質を環境中に放出したという点で、私たちがかって経験したことのない原発事故でした。事故から3年半を経た1989年10月に旧ソ連政府は、Fig. 1 に示しましたような経緯を経て国際原子力機関(IAEA)に対し、周辺の環境と住民への影響を専門家によって調査する国際的なプロジェクトの実施を要請しました。それは放射性物質の影響から住民を守るためにソ連政府が実施した対策の妥当性を総合的に評価することが主な目的でした。従って事故現場の発電所職員、消防救急隊員、プリピアチを含む強制退去した30 Km圏内の住民、立入り禁止地区の除染作業の従事者は直接対象とはなっていません(Table 1)。（付表　“チェルノブイリ原発事故の被災者”）これを受けて重松逸造放射線影響研究所理事長を委員長とした国際諮問委員会(IAC)が設けられ、その監督のもとに1990年5月から大掛かりな調査が開始され私も委員として参加する機会をえました。調査の結果は、1991年5月に最終報告書にまとめられて公表されました。

報告書の内容は、

Task 1　歴史的記述
Task 2　環境汚染
Task 3　住民の放射線被爆
Task 4　健康への影響
Task 5　放射線からの防護対策　　からなっています。

5つのTaskの中で国際チェルノブイリプロジェクトが独自に調査を行いましたTask 2、環境汚染について、IAEAは「プロジェクトで実施された測定と評価は提供された公式地図に報告されているセシウムに関する地表汚染評価値を全般的に確証した。またプロジェクトチームが得た限定された土壌サンプルの分析結果は、プルトニウムの地表汚染評価値と一致したが、ストロンチウムに関してはそれより低かった」という結論に達しました。

また、Task 3、住民の放射線被爆についての結論は、「線量推定に関する公式の手順は科学的にほぼ適切であった。使用された方法論は、線量を過小評価しないような結果を得ようとするものであった。外部及び体内に取り込まれたセシウムによる内部被爆についてモニターされた個々の住民に関する独自のプロジェクトの推定値は、公式に報告された線量推定値よりも低かった」というものでした。

Task 4、健康への影響については、「このプロジェクトの下での調査汚染居住地区及び調査対照居住地区の両方の住民に、放射線とは関係のない顕著な健康の変調があったが、放射線被爆に直接起因するとみられる健康の変調はなかった。事故は継続的かつ高いレベルの不安に起因する心配とストレスの面では相当な負の精神影響を及ぼし、その不安の発生は汚染地域を超えて広がった。ソ連で起きている社会経済及び政治的な変化が一層輪をか

けた。検討された公式データは、白血病または癌の発生について著しい増加を示していなかった。しかしある種の腫瘍の発生率の増加の可能性を排除できるほど、これらのデータは詳細ではなかった。報告された小児の甲状腺吸収線量の推定値は、将来統計的に検出可能な甲状腺腫瘍の発生率の増加をもたらすかもしれない程度である。プロジェクトによって推定された線量と、現在受入れられている放射線リスク推定に基づくと、大規模な良く計画された長期にわたる疫学調査によいってさえも、全癌または遺伝的影響の自然発生率に対する将来の増加を識別することは困難であろう。」と述べています。

【国際チェルノブイリプロジェクト Task 4（健康への影響調査）の結論と反響】

Task 4 の健康への影響調査の作業として本プロジェクトは、チェルノブイリ事故による病気が増加しているとの報告を評価し、さらに疑問に答えるために、2段階のアプローチを用いました。即ち、第1のステップは、主要な医療センターと研究所の公式データを見直すこと、第2のステップは、疫学的にデザインされた汚染居住地区と対照居住地区の住民の両方を調査し、結果を比較することでした。

第2のステップを行うための、field tripのデザインとして、医療チームは、居住地区の選択を行いましたが、これは社会経済構造を考慮し種々の地域社会を代表するような居住地区を選ぶように心掛ました。また放射線量について、汚染地域の選択は^{137}Csが15 Ci/km^2(555 kBq/m^2)以上の地域を、ロシア、白ロシア、ウクライナ3共和国各々から2ケ所以上、対照地域としては、汚染地域の周辺で、^{137}Csが1 Ci/km^2(37 kBq/m^2)以下の地域より少なくとも20 Km離れた地域を、やはり3共和国とも2カ所以上とし、Fig. 2 に示します13地域－汚染地域7カ所、対照地域6カ所－が選ばれました。

また、対象者の選択には、予想される臨床的健康影響を検出できるようにデザインされた統計サンプリング方式を用い、2才、5才、10才、40才、60才の各年齢群が汚染地域と対照地域から選ばれました。この方法は、検査対象住民の10%から80%の標本を得ることができるように設定されており、合計で、1,356人が調査を受けました。

field tripで実施された調査項目は、これらの実施項目は調査対象者の精神心理状態を含めた全身状態が、ほぼ把握できるように設定されていますが、本日は、このうち、特に問題になっています甲状腺と血液検査について説明します。

甲状腺については、触診及び超音波による甲状腺検査及び血中甲状腺ホルモン(TSH, FT4)の測定が行われました。Table 2 は年齢及び居住地域別に触診と、超音波検査による甲状腺結節の発生者数と頻度が百分率で示されています。いずれの年齢においても汚染地域と対照地域で結節の頻度に差がないことがお解りいただけると思います。

Table 3 はこれら甲状腺結節の超音波検査上の特徴を両地域で比べていますが、いづれの地域もHypoechoicを示す者が半数以上を占め、やはり両地域間で明らかな違いは認められません。TSH, FT4など血中甲状腺ホルモンの測定においても同様の結果です。即ち甲状腺については、その機能においても甲状腺の大きさ、さらに結節の頻度とその超音波検査上の所見の特徴においてもIAEA独自の調査では、汚染地域と対照地域で有意の違いが認めらず、現時点で放射線の影響による甲状腺疾患の増加は現われていないとの結論に達しました。

これに対し、Kazakovらは、1992年10月22日号のNatureに、Belarusの小児に甲状腺癌の発

生が増加していることを報告し、WHOのBaverstochらも同じ号にこれ支持する意見を発表しました。
そして更に彼等への反論としてFig. 2 に示します３つのpaper、即ちイギリスのReevesらはLancetに、また日本の重松ら、アメリカのRonらはNatureに投稿し、疾患の発生頻度を論ずる場合、母集団を明確にする必要があることを強調しました。目下、チェルノブイリ事故の後影響としての甲状腺癌の発生状況は、世界中の放射線研究者が注意深く見守るところとなっています。
次に２番目の問題として、血液検査について述べます。血液検査としては、WBC, RBC, Hb, Ht, MCV, PLT,白血球分類が行われました。Fig. 3 はこのうち最も放射線の影響を受けやすく、免疫機能にも関係のあるリンパ球の絶対値を示します。小児期にリンパ球の絶対数は多く、10才以後次第に成人の値まで減少します。しかし、横軸に示すいづれの年齢群においても汚染地域と対照地域間の差はなく、やはり放射線による明らかな影響はないものと考えられました。このことは、RBCやHb値など他の血液検査項目についても同様でした。
また、このリンパ球について染色体検査を行いましたところ、一部にdicentricsやringという異常染色体を認めました。しかし、その発生頻度は両地域間で差はなく、血液検査についいても、明らかな放射線の影響は現われていないものと考えました(Fig. 4)。
一方、白血病の発生状況に関する調査のうち、Table 4 はウクライナ共和国の腫瘍登録データを示しますが、1986年の事故以後特に汚染地域で白血病が増加しているという傾向はないようです。

以上国際チェルノブイリプロジェクトによる血液疾患の調査結果をご紹介しましたが、その後1993年のEuropean Journal of Cancerに“Children Leukemia Foffowing the Chernobyl Accident云々”というタイトルのpaperが投稿され、旧ソ連を含めたヨーロッパ各国の小児白血病とリンパ腫の発生状況が報告されました。Table 5 はオーストリア、ブルガリア、チェコスロバキア、デンマークなど１７カ国の1980年から1985年までと、1987年から1988年の白血病－リンパ腫の症例数と予測症例数を示していますが、これによりましても事故前後の明らかな白血病－リンパ腫の増加はみられていないようです。
一方本日、ご出席のイワノフ博士から昨年の６月の第１回チェルノブイリ笹川医療協力シンポジウムにおいてBeralusの血液疾患の発生状況のご報告があり、日本の新聞でも報道されましたことをご紹介致します。詳細については、イワノフ博士よりご報告があるものと思われます。現状の全体像を正確に把握しながら、今後、長期にわたる組織的な疫学調査と計画的医学研究、医療体制の整備が要請されています。すでにWHO始め各種団体の国際協力が各々の計画を実行しつつあり、日本でもこれらに多大の貢献をして参りましたので、今後共協力してゆきたいと考えています。

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Fig 1.

CHRONOLOGY OF MAJOR EVENTS

26 April 1986	Accident occurs 01:23. Governmental Commission formed
27 April 1986	Evacuation of Pripyat takes place
6 May 1986	End of 10 days of atmospheric release of radioactive material from the core
6 May 1986	Introduction of 'temporary permissible levels' for drinking water and foodstuffs
6 May 1986	Evacuation of the population within the prohibited zone completed
31 May 1986	Revision of 'temporary permissible levels'
May 1986	'Temporary dose limits' for the population set at 100 mSv (internal and external) annual total dose
July 1986	First summarized contamination map (not published until 1989)
November 1986	Completion of the 'sarcophagus' construction
— 1987 —	'Temporary dose limits' for the population reduced to 30 mSv annual total dose (subsequently lowered to 25 mSv for 1988)
April 1987	Completion of the work begun in May 1986 for protecting the water system
December 1987	Revision of the 'temporary permissible levels' established 31 May 1986
— 1988 —	'Temporary dose limits' for the population reduced to 25 mSv annual total dose
September 1988	Council of Ministers of USSR adopts the 350 mSv lifetime dose for relocation to be implemented as of 1 January 1990
March 1989	Contamination maps officially published in the three Republics
April 1989	BSSR Academy of Sciences registers disagreement with the 350 mSv lifetime dose concept and makes new proposals
October 1989	USSR requests the IAEA to organize an international assessment of the consequences of the accident and the protective measures taken

Table 1

チェルノブイル原発事故の被災者

1．発電所作業員およびその家族 技師職員、消防救急隊員ら急性障害225名(1 Gy以上)を含む	4万5000人
2．30 Km圏内から移住させられた人達 (外部被曝 15〜50 mGy、皮膚被曝 100〜200 mGy)	11万5000人
3．除染作業従事者（250 mSv以下）	20万人以上
4．三共和国の汚染地区居住者（5〜40 Ci/Km²）	82万5000人

Table: 2

Prevalence of Thyroid Nodules by Age and Settlement Type*

Age, y	Contaminated Settlement No. (%)	Control Settlement No. (%)
5		
Nodule palpated	0 (0)	1 (0.8)
Nodule on sonogram	1 (0.6)	0 (0)
10		
Nodule palpated	2 (1.2)	1 (0.8)
Nodule on sonogram	1 (0.6)	1 (0.8)
40		
Nodule palpated	5 (3.7)	2 (1.7)
Nodule on sonogram	21 (15.7)	15 (12.8)
60		
Nodule palpated	6 (4.9)	8 (7.2)
Nodule on sonogram	22 (17.9)	21 (19.0)

(FA Mettler et al; JAMA 1992)

Table 3

Ultrasonographic Characteristics of Discrete Thyroid Nodules in Subjects From Highly Contaminated and Control Settlements

	Simple Cyst	Complex Cyst	Hypoechoic	Isoechoic	Hyperechoic	Diameter, mm Mean (SD)
Highly contaminated settlements, No. (%) (n=45)	0 (0)	12 (27)	25 (56)	6 (13)	2 (4)	11 (7)
Control settlements, No. (%) (n=36)	1 (3)	7 (19)	23 (64)	3 (8)	2 (6)	13 (8)
Total, No. (%) (N=81)	1 (1)	19 (24)	48 (59)	9 (11)	4 (5)	...

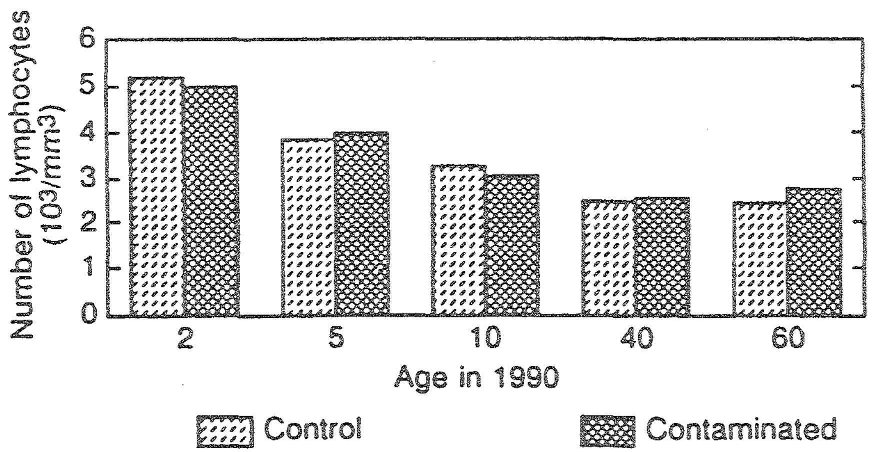
(FA Mettler et al; JAMA 1992)

Fig 2

Counterarguments

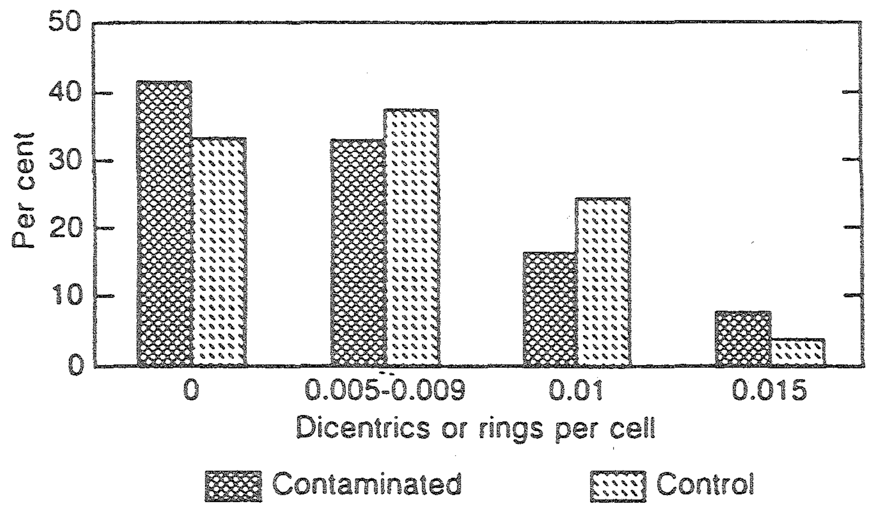
- A. Prisyazhink, G. K. Reeves et al: Cancer in the Ukraine, post-Chernobyl,
  Lancet 338, 1991
- I. Shigematsu : Childhood thyroid cancer in Belarus, Nature 359, 1992
- E. Ron : Thyroid cancer incidence, Nature 360, 1992

Fig 3



Absolute lymphocyte count by age in control and contaminated settlements.

Fig 4.



Cytogenetic data: per cent of dicentrics or rings per cell.

Table 4

Incidence of Lymphatic/Haematopoietic Cancer in Three Contaminated Regions of the UkrSSR

Year	Rate of incidence per 100 000 persons		
	In three contaminated regions		Rate in entire UkrSSR
	Rate	Number of cases	
1980	4.9	8	11.0
1981	5.6	9	12.0
1982	13.3	21	12.1
1983	11.5	18	12.5
1984	12.4	19	12.6
1985	8.6	13	13.4
1986	10.1	16	13.0
1987	16.6	24	14.1
1988	16.4	23	15.0
1989	15.8	22	15.0

Table. 5

European Childhood Leukaemia-Lymphoma Incidence Study

	Baseline (1980–1985) Cases	Baseline (1980–1985) Cumulative rate	Observed (1987–1988) Cases	Observed (1987–1988) Cumulative rate	Expected (1987–1988)* Cases
Austria	374	657	52†	588†	58.4
Bulgaria					
Region 1, Region 2	Not available				
Czechoslovakia					
Region 1	211	526	70	555	64.5
Region 2	210	565	71	616	65.2
Region 3	405	548	149	617	132.9
Denmark	253	652	89	783	76.4
Finland	285	745	81	638	94.7
France					
Region 3	257	573	126	598	122.2
Germany					
ex-GDR					
Region 1	157	571	47	512	52.2
Region 2	143	506	51	539	47.6
Region 3	378	507	126	492	128.6
ex-FRG					
Region 1	1512	604	486	619	475.8
Region 2	471	586	161	618	151.7
Region 3	243	493	88	542	80.1
Hungary					
Region 1	222	450	88	575	66.6
Region 2	205	464	71	535	61.9
Italy					
Region 1	244	714	60	669	63.7
Netherlands	687	603	200	561	215.5
Norway	197	604	29†	550†	31.7
Poland	1431	350	516	396	498.9
Slovenia	91	515	31	558	628.2
Sweden					
Region 1	65	679	25	830	20.6
Region 2	10	500	9	1458	3.0
Region 3	320	657	123	781	103.5
Switzerland					
Region 2	67	624	20	836	15.0
Region 3	20	789	4	496	6.4
Region 4	38	562	13	578	12.7
United Kingdom					
Region 1	2076	554	701	563	688.9
Region 2	203	517	92	737	64.5
Region 3	61	636	21	679	19.7
ex-USSR					
Region 1, Region 3	Not available				
Region 4	235	514	79	493	82.1

* Based on age-specific incidence 1980–1985.
† 1987 data only.

(Eur J Cancer, 29A, 1993)

S2

主な出来事の年表

1986年4月26日	01:23（モスクワ時間）に事故発生。政府委員会結成。
1986年4月27日	プリピャチの避難実施。
1986年5月6日	炉心から大気への10日間の放射性物質の放出が停止。 飲料水及び食料品の"暫定許容レベル"の導入。 立入禁止区域内の住民の避難が完了。
1986年5月31日	"暫定許容レベル"の改訂。
1986年5月	一般公衆に対する"暫定線量限度"を年線量 100 mSv（内部及び外部被曝）に設定。
1986年7月	最初の概略汚染地図作成（1989年まで公開せず）。
1986年11月	"石棺"の建設完了。
— 1987 —	一般公衆の"暫定線量限度"を年線量30mSvに引き下げた （続いて、1988年に25mSvに下げた）。
1987年4月	1986年5月に開始した水系保護のための作業完了。
1987年12月	1986年5月31日決定の"暫定許容レベル"の改訂。
— 1988 —	一般公衆の"暫定線量限度"を年線量25 mSvに引き下げた。
1988年9月	ＵＳＳＲの閣僚会議は、1990年1月1日付で施行される移住適用のための生涯線量を350mSvとした。
1989年3月	3共和国で汚染に関する公式の地図を公表。
1989年4月	ＢＳＳＲ科学アカデミーが350mSv生涯線量概念に反対を表明し、新しい提案をした。
1989年10月	ソ連政府が事故の影響および実施された防護手段について国際的アセスメントを組織するようＩＡＥＡに要請

国際チェルノブイル計画

1990年2月

準備会議

準　　備

1990年3月

実態調査

作業計画

1990年4月

国際諮問委員会会合

実　　施

1990年5月～1991年1月

作業計画の実施

- 歴史的記述
- 環境汚染
- 放射線被曝
- 健康影響
- 防護手段

ドラフトレポート

1991年2月

報告書の作成

最終報告書：報告

1991年3月

国際諮問委員会会合

1991年5月21日～24日

国際会議

作業計画

タスク１：現在の放射線の状況につながる出来事の歴史的記述の編集（付録を参照）

タスク２：環境汚染アセスメントの評価

タスク３：放射線量アセスメントの評価

タスク４：放射線被曝による臨床的な健康上の影響のアセスメントおよび一般的な健康状況の評価

タスク５：防護手段の評価

S-5

Task 2： 環境汚染

一般的結論

プロジェクトの下で実施された測定とアセスメントは、プロジェクトに提供された公式地図で報告されているセシウムに関する地表汚染評価値のレベルを一般的に確証した。プロジェクトチームが得た限定された土壌サンプルの分析結果は、プルトニウムの地表汚染評価値と一致したが、ストロンチウムに関してはそれよりも低かった。

飲料水中および調査地域からの食品中で測定された放射性核種の濃度は、食品の自由貿易のために確立された国際的なガイドラインを大幅に下回り、また、多くの場合、検出限度以下であった。

5-6

Task 3：
住民の放射線被曝

一般的結論

線量推定に関する公式の手順は、科学的には適切であった。使用された方法論は、線量を過小評価しないような結果を得ようとするものであった。外部および体内に取り込まれたセシウムによる内部被曝についてモニターされた個々の住民に関する独自の測定値は、計算モデルに基づいて期待される結果を与えた。調査汚染居住地区に関する独自のプロジェクトの推定値は、公式に報告された線量推定値よりも低かった(注3)。

8-7

Task 4：

健康影響

一般的結論

このプロジェクトの下での調査汚染居住地区および調査対照居住地区の両方の住民に、放射線とは関係のない顕著な健康の変調があったが、放射線被曝に直接起因するとみられる健康の変調はなかった。事故は、継続的かつ高いレベルの不安に起因する心配とストレスの面で相当な負の精神的影響を及ぼし、その不安の発生は汚染地域を超えて拡った。ソ連で起きている社会経済および政治的な変化が、これにいっそう輪をかけた。

検討された公式データは、白血病またはがんの発生について著しい増加を示してはいなかった。しかし、ある種の腫瘍の発生率の増加の可能性を排除できるほど、これらのデータは詳細ではなかった。報告された小児の甲状腺吸収線量の推定値は、将来、統計的に検出可能な甲状腺腫瘍の発生率の増加をもたらすかもしれない程度である。

プロジェクトによって推定された線量と、現在受け入れられている放射線リスク推定に基づく大規模な長期にわたる疫学的調査によっても、全がんまたは遺伝的影響の自然発生率に対する将来の増加を識別することは困難であろう。

S-8

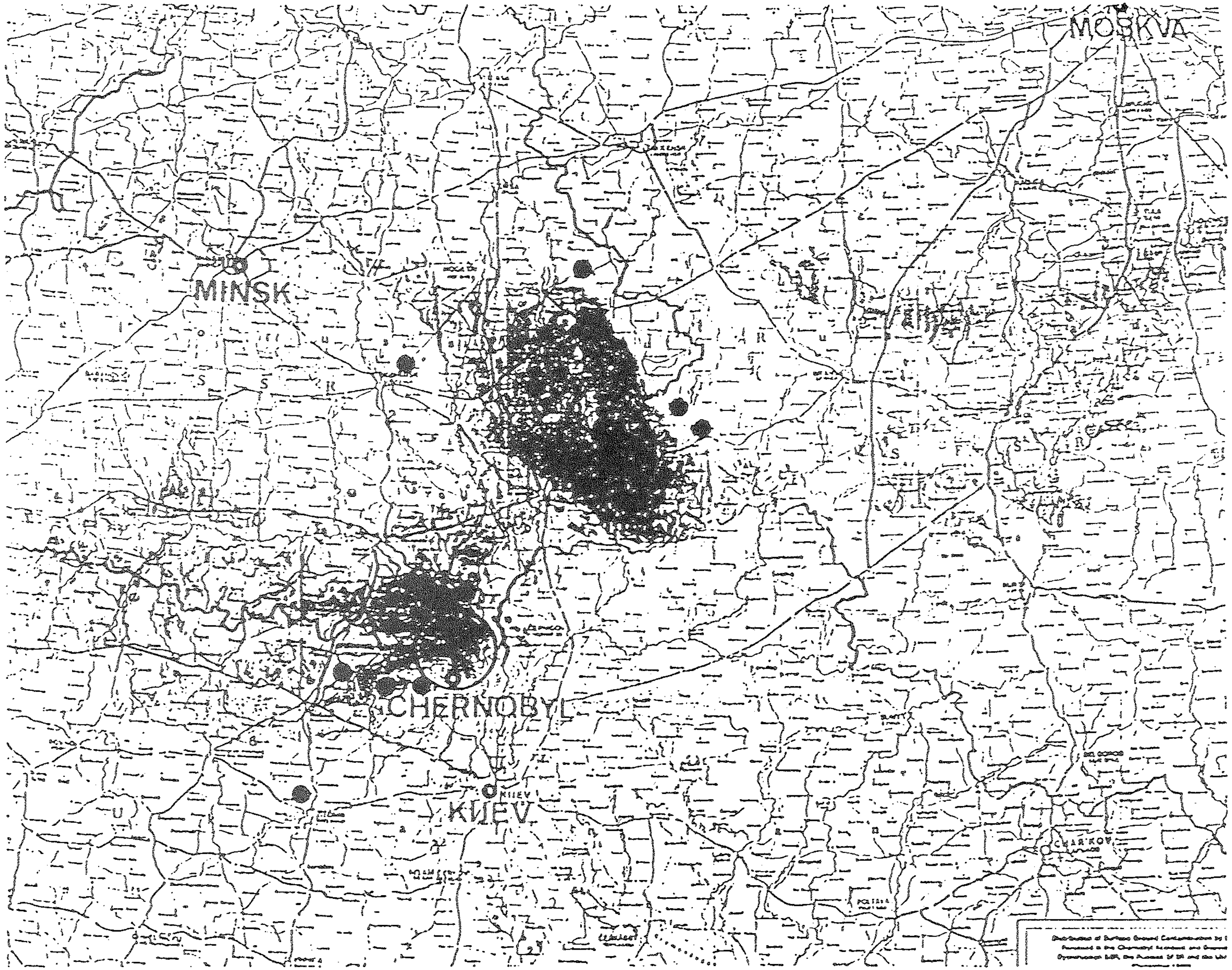
公式データ評価項目

— 線量評価
— 貧血症
— 免疫機能
— 甲状腺機能
— 甲状腺腫
— 生年月日
— 胎児及び遺伝的影響
— 放射線白内障
— 一般的健康統計
— 鉛の毒性
— 栄養
— ヨウ素予防法
— 健康登録
— がん統計
— 心理学的局面

5-8

フィールド調査デザイン

S-9



IAEAで作成したセシウム(^{137}Cs)汚染地図と調査班の検診地区

(グリーン丸 1 Ci/km^{2}以下，ブルー丸15Ci/km^{2}以上，○印は30km圏立入禁止地域を示す)．

S-10

グループ１：２才児　1988年生まれ（事故後）

グループ２：５才児　1985年生まれ（事故時に幼児であった）

グループ３：10才児　1980年生まれ

グループ４：40才　1950年生まれ

グループ５：60才　1930年生まれ

S-11

医療チームの調査した人数

共和国	居住地	グループ1 出生年 1988	グループ2 出生年 1985	グループ3 出生年 1980	グループ4 出生年 1950	グループ5 出生年 1930	グループ6 その他 1988	合計
白ロシア	調査汚染	57	77	72	53	50	101	410
	調査対照	45	43	45	46	37	73	289
ロシア	調査汚染	45	49	47	42	41	3	227
	調査対照	46	41	46	44	42	3	222
ウクライナ	調査汚染	45	40	42	41	38	10	216
	調査対照	36	43	44	30	38	101	292
合計	調査汚染	147	166	161	136	129	114	853
	調査対照	127	127	135	120	117	177	803
合計		274	293	296	256	246	291	1,656

S-12

実地調査項目

- 態度
- ストレス効果
- 栄養
- ヨウ素予防法
- 血液学的状態
- 鉛の毒性
- 成長パラメータ
- 甲状腺機能
- 甲状腺状態
- 病歴
- 一般的体格測定
- 限定的な細胞遺伝学検査

S-13

Prevalence of Thyroid Nodules by Age and Settlement Type*

Age, y	Contaminated Settlement No. (%)	Control Settlement No. (%)
5		
Nodule palpated	0 (0)	1 (0.8)
Nodule on sonogram	1 (0.6)	0 (0)
10		
Nodule palpated	2 (1.2)	1 (0.8)
Nodule on sonogram	1 (0.6)	1 (0.8)
40		
Nodule palpated	5 (3.7)	2 (1.7)
Nodule on sonogram	21 (15.7)	15 (12.8)
60		
Nodule palpated	6 (4.9)	8 (7.2)
Nodule on sonogram	22 (17.9)	21 (19.0)

(FA Mettler et al; JAMA 1992)

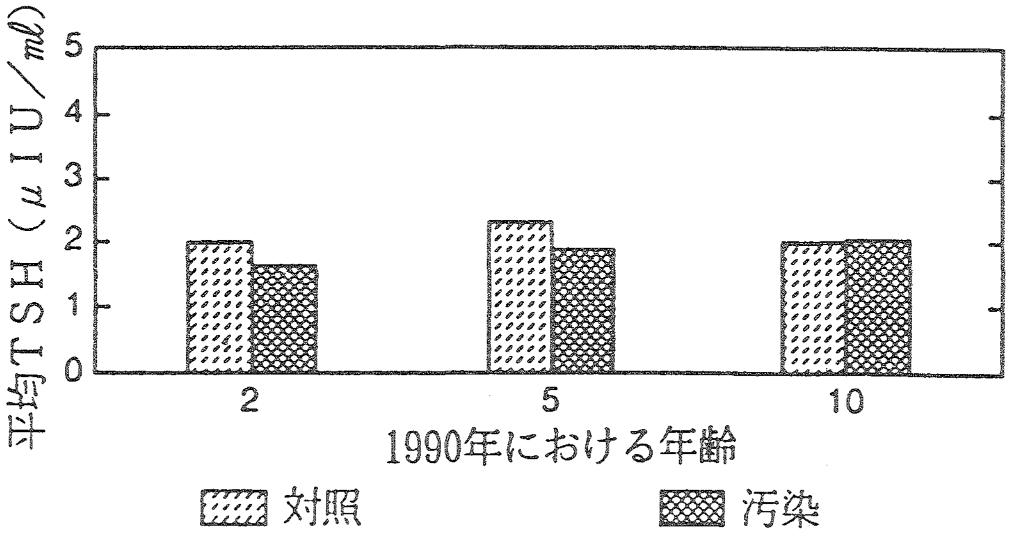
S-14

Ultrasonographic Characteristics of Discrete Thyroid Nodules in Subjects From Highly Contaminated and Control Settlements

	Simple Cyst	Complex Cyst	Hypoechoic	Isoechoic	Hyperechoic	Diameter, mm Mean (SD)
Highly contaminated settlements, No. (%) (n=45)	0 (0)	12 (27)	25 (56)	6 (13)	2 (4)	11 (7)
Control settlements, No. (%) (n=36)	1 (3)	7 (19)	23 (64)	3 (8)	2 (6)	13 (8)
Total, No. (%) (N=81)	1 (1)	19 (24)	48 (59)	9 (11)	4 (5)	...

(FA Mettler et al; JAMA 1992)

S-15



対照および汚染居住地の子供達における平均甲状腺刺激ホルモン（TSH）。μIUは国際単位（本文をみよ。）正常値巾は0.6－5.0μIU

S-16

- V.S. Kazakov et al : Thyroid cancer after Chernobyl, Nature 396, 1992

TABLE 1 Incidence of thyroid cancer in children in Belarus

Region of Belarus	Years 1986	1987	1988	1989	1990	1991	1992*	Total
Brest	0	0	1	1	6	5	5	18
Vitebsk	0	0	0	0	1	3	0	4
Gomel	1	2	1	2	14	38	13	71
Grodno	1	1	1	2	0	2	6	13
Minsk	0	1	1	1	1	4	4	12
Mogilev	0	0	0	0	2	1	1	4
Minsk City	0	0	1	0	5	2	1	9
Total	2	4	5	6	29	55	30	131

* Six months of 1992.

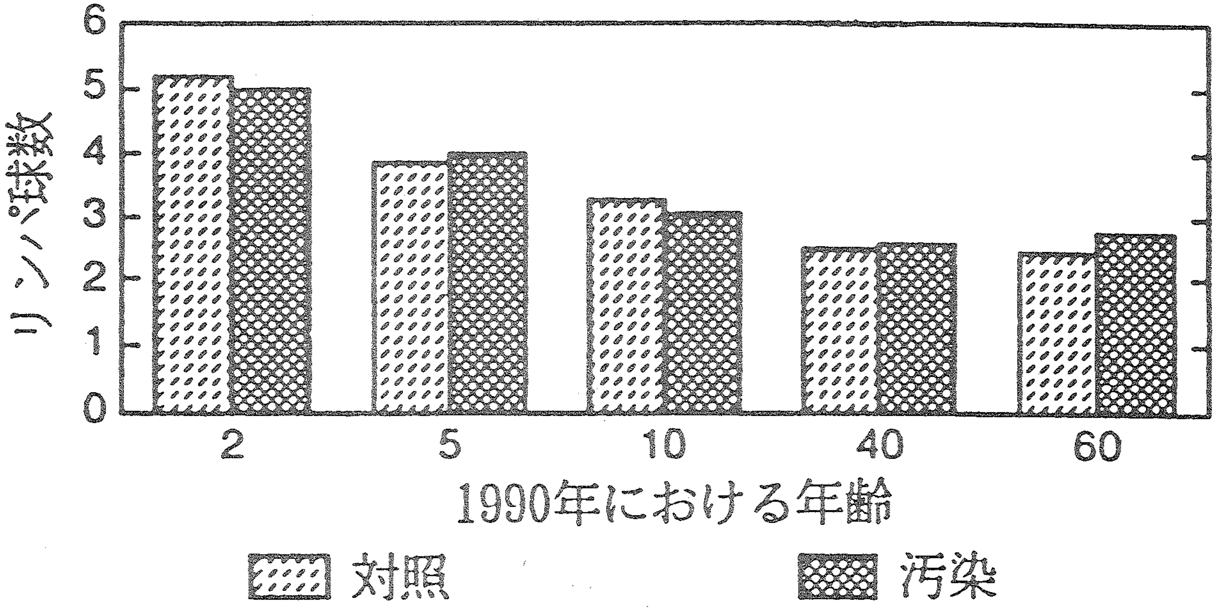
- K. Beverstock et al : Thyroid cancer after Chernobyl, Nature 359, 1992

S-17

Counterarguments

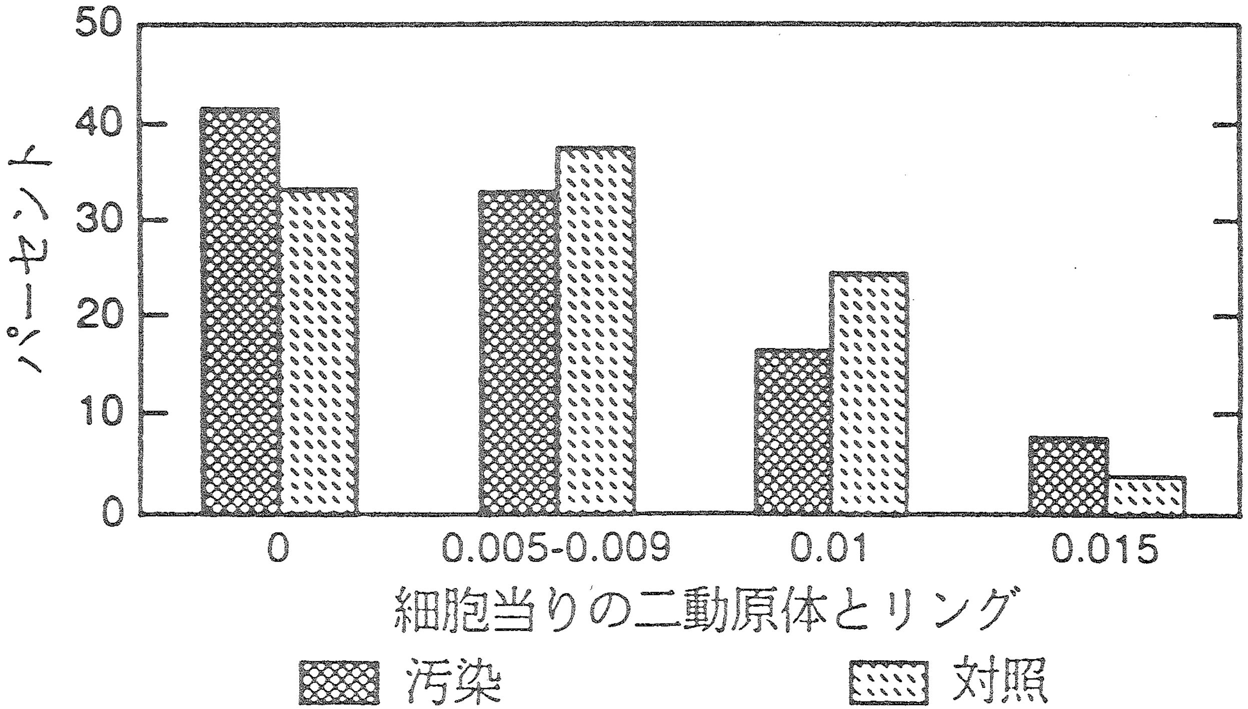
- A.Prisyazhink, G.K.Reeves et al: Cancer in the Ukraine, post-Chernobyl, Lancet 338, 1991
- I.Shigematsu : Childhood thyroid cancer in Belarus, Nature 359, 1992
- E.Ron : Thyroid cancer incidence, Nature 360, 1992

S-18



対照および汚染居住地の各年齢群における
リンパ球数

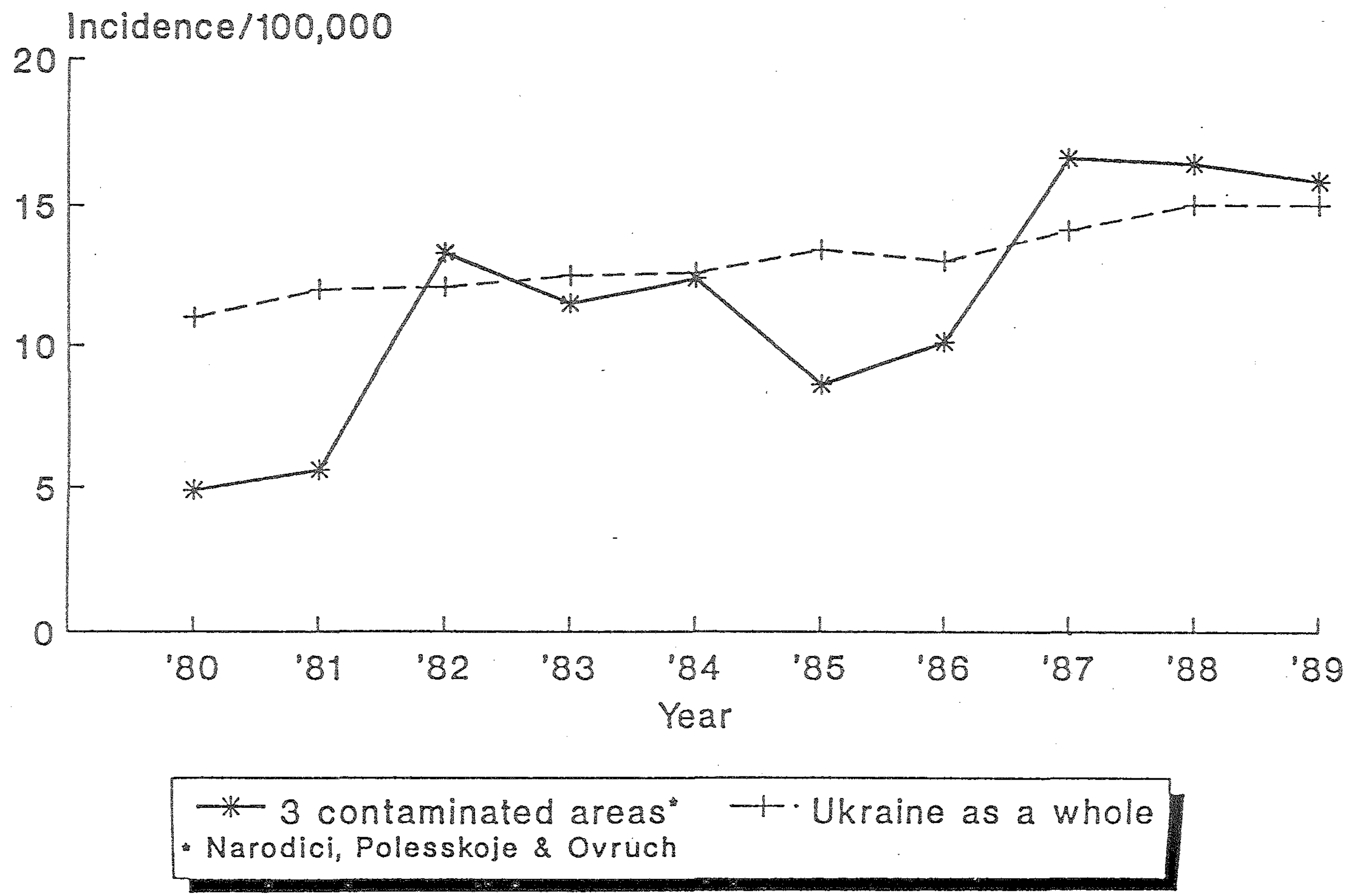
S-19



細胞当りの二動原体とリングのパーセント

S-20

Incidence of Hematopoietic Malignancies
Ukraine Tumor Registry Data



S-21

European Childhood Leukaemia-Lymphoma Incidence Study

	Bascline(1980-1985)		Observed(1987-1988)		Expected(1987-1988)*
	Cases	Cumulative rate	Cases	Cumulative rate	Cases
Austria	374	657	52+	588+	58.4
Finland	285	745	81	638	94.7
Italy	244	714	60	669	63.7
Poland	1431	350	516	396	498.9
ex-USSR	235	514	79	493	82.1

* Based on age-specific incidence 1980-1985.
+ 1987 data only.

(Eur J Cancer, 29A, 1993)

S-22

ミンスクのイワノフ博士が発表した
白血病と造血器障害の発生頻度
（1979-82,1983-85は、いずれも年間平均の数）

	1979-82	1983-85	1986	1987	1988
【ゴメリ地域】					
慢性骨髄性白血病	21	17	15	18	40
慢性リンパ性白血病	49	44	45	45	97
骨　髄　腫	15	16	17	28	26
再生不良性貧血病	11	13	14	10	21
【モギリョフ地域】					
慢性リンパ性白血病	55	49	43	78	65

（読売新聞 1992. 7. 2.付）

S-1 Session 4, Slides for Keynote by Prof. A. Kuramoto <For English>

Evaluation of Effects of Chernobyl Accident

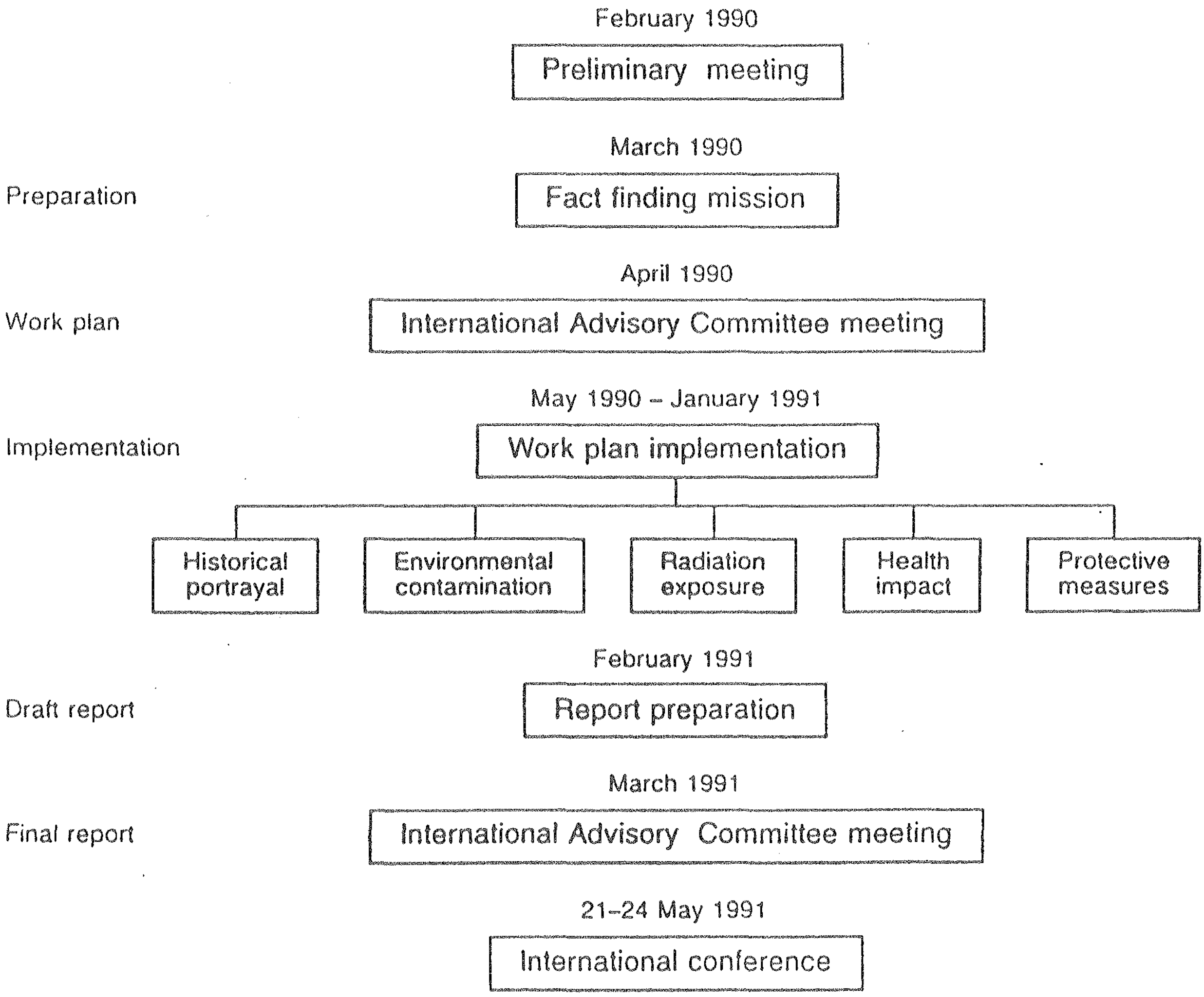
Atsushi Kuramoto
Director
Research Institute for Nuclear Medicine and Biology
Hiroshima University

S-2

CHRONOLOGY OF MAJOR EVENTS

26 April 1986	Accident occurs 01:23. Governmental Commission formed
27 April 1986	Evacuation of Pripyat takes place
6 May 1986	End of 10 days of atmospheric release of radioactive material from the core
6 May 1986	Introduction of 'temporary permissible levels' for drinking water and foodstuffs
6 May 1986	Evacuation of the population within the prohibited zone completed
31 May 1986	Revision of 'temporary permissible levels'
May 1986	'Temporary dose limits' for the population set at 100 mSv (internal and external) annual total dose
July 1986	First summarized contamination map (not published until 1989)
November 1986	Completion of the 'sarcophagus' construction
— 1987 —	'Temporary dose limits' for the population reduced to 30 mSv annual total dose (subsequently lowered to 25 mSv for 1988)
April 1987	Completion of the work begun in May 1986 for protecting the water system
December 1987	Revision of the 'temporary permissible levels' established 31 May 1986
— 1988 —	'Temporary dose limits' for the population reduced to 25 mSv annual total dose
September 1988	Council of Ministers of USSR adopts the 350 mSv lifetime dose for relocation to be implemented as of 1 January 1990
March 1989	Contamination maps officially published in the three Republics
April 1989	BSSR Academy of Sciences registers disagreement with the 350 mSv lifetime dose concept and makes new proposals
October 1989	USSR requests the IAEA to organize an international assessment of the consequences of the accident and the protective measures taken

S-3


February 1990
Preliminary meeting
March 1990
Preparation
Fact finding mission
April 1990
Work plan
International Advisory Committee meeting
May 1990 – January 1991
Implementation
Work plan implementation
Historical portrayal
Environmental contamination
Radiation exposure
Health impact
Protective measures
February 1991
Draft report
Report preparation
March 1991
Final report
International Advisory Committee meeting
21–24 May 1991
International conference

8-4

The work covered five areas or 'tasks':

Task 1: Compilation of a historical portrayal of events leading to the current radiological situation (see Appendix)

Task 2: Evaluation of the environmental contamination assessments

Task 3: Evaluation of the radiation exposure assessments

Task 4: Assessment of clinical health effects from radiation exposure and evaluation of the general health situation

Task 5: Evaluation of protective measures

S-5

Task 2 :
Evaluation of the environmental contamination assessments

General Conclusions

Measurements and assessments carried out under the Project provided general corroboration of the levels of surface contamination for caesium as reported in the official maps that were made available to the Project. Analytical results from a limited set of soil samples obtained by the Project teams corresponded to the surface contamination estimates for plutonium but were lower than those for strontium.

The concentrations of radionuclides measured in drinking water and, in most cases, in food from the areas investigated were significantly below guideline levels for radionuclide contamination of food moving in international trade and in many cases were below the limit of detection.

S-6

Task 3 :
Evaluation of the radiation exposure assessments

General Conclusions

The official procedures for estimating doses were scientifically sound. The methodologies that were used were intended to provide results that would not underestimate the doses. Independent measurements in individual residents monitored for external and for internal exposure from caesium incorporated into the body yielded results that would be predicted on the basis of calculational models. Independent Project estimates for the surveyed contaminated settlements were lower than the officially reported dose estimates[3].

B-7

Task 4 :
Assessment of Clinical Health Effects Conclusions

Adverse health effects attributable to radiation have not been substantiated either by the local studies, which were adequately performed, or by the studies conducted during the Project.

Possible future increases in cancer incidence and/or hereditary defects, caused by Chernobyl-related radiation exposure, will be difficult to discern.

C2-7

Task 4 :
Assessment of Clinical Health Effects

General Conclusions

There were significant non-radiation-related health disorders in the populations of both surveyed contaminated and surveyed control settlements studied under the Project, but no health disorders that could be attributed directly to radiation exposure. The accident had substantial negative psychological consequences in terms of anxiety and stress due to the continuing and high levels of uncertainty, the occurrence of which extended beyond the contaminated areas of concern. These were compounded by socioeconomic and political changes occurring in the USSR.

The official data that were examined did not indicate a marked increase in the incidence of leukaemia or cancers. However, the data were not detailed enough to exclude the possibility of an increase in the incidence of some tumour types. Reported absorbed thyroid dose estimates in children are such that there may be a statistically detectable increase in the incidence of thyroid tumours in the future.

On the basis of the doses estimated by the Project and currently accepted radiation risk estimates, future increases over the natural incidence of cancers or hereditary effects would be difficult to discern, even with large and well designed long term epidemiological studies.

S-8

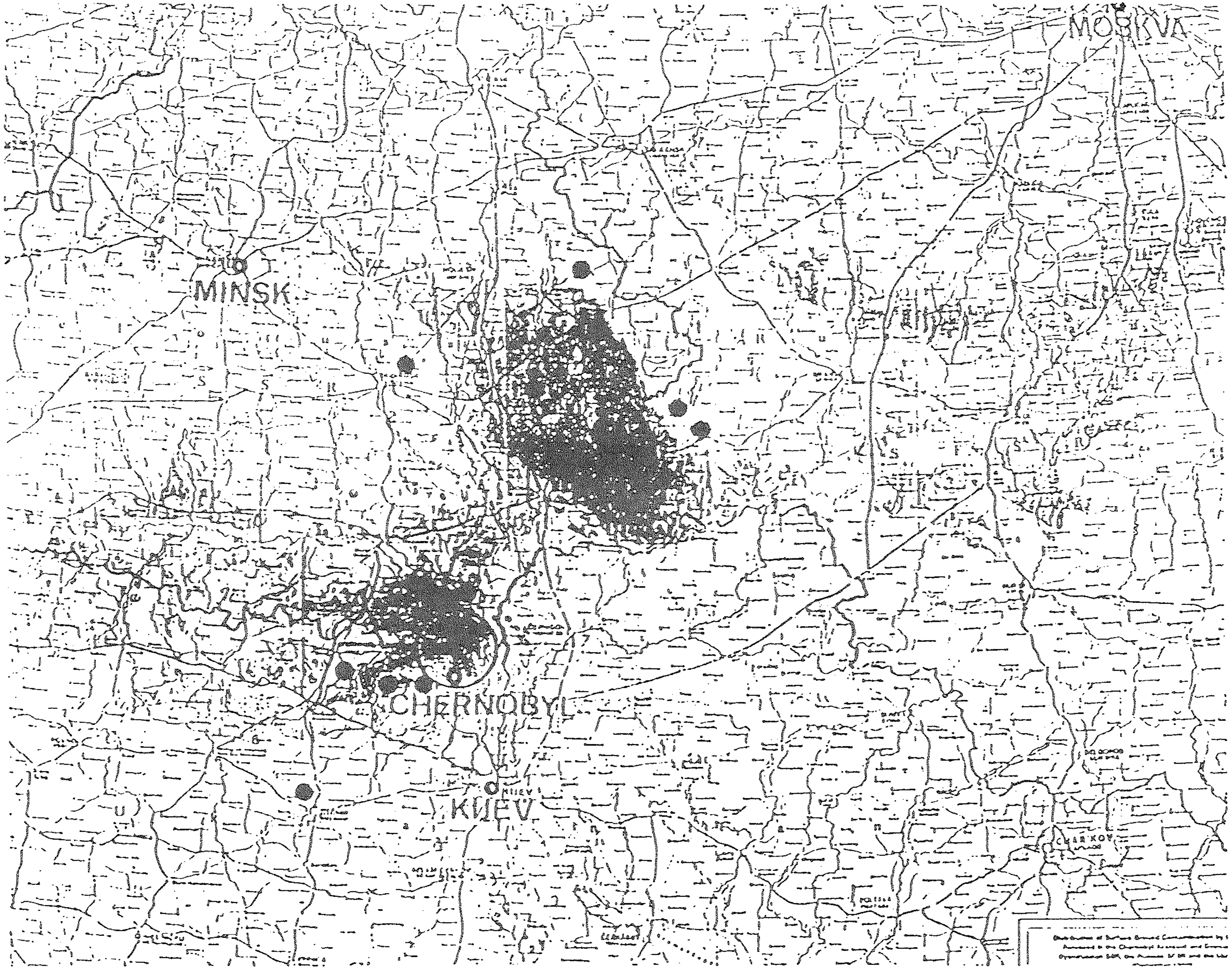
The first missions located and assessed official data relative to the following areas of concern:

- Dosimetry
- Anaemia
- Immune function
- Thyroid function
- Thyroid goitre
- Birth data
- Foetal and genetic effects
- Radiation cataracts
- General health statistics
- Lead poisoning
- Nutrition
- Iodine prophylaxis
- Health registers
- Cancer statistics
- Psychological aspects.

S-9

Field Trip Design

⑨



IAEAで作成したセシウム(^{137}Cs)汚染地図と調査班の検診地区

(グリーン丸1Ci/km²以下，ブルー丸15Ci/km²以上，○印は30km圏立入禁止地域を示す)．

S-10

Group 1 : 2 year olds , Born in 1988
(after the accident)

Group 2 : 5 year olds , Born in 1986
(infants at the time of the accident)

Group 3 : 10 year olds , Born in 1980

Group 4 : 40 year olds , Born in 1950

Group 5 : 60 year olds , Born in 1930

Number of Persons Examined by the Medical Team

Republic	Settlement	Group 1 Year of birth: 1988	Group 2 Year of birth: 1985	Group 3 Year of birth: 1980	Group 4 Year of birth: 1950	Group 5 Year of birth: 1930	Group 6 Other	Total
BSSR	Surveyed contaminated	57	77	72	53	50	101	410
	Surveyed control	45	43	45	46	37	73	289
RSFSR	Surveyed contaminated	45	49	47	42	41	3	227
	Surveyed control	46	41	46	44	42	3	222
UkrSSR	Surveyed contaminated	45	40	42	41	38	10	216
	Surveyed control	36	43	44	30	38	101	292
Total	Surveyed contaminated	147	166	161	136	129	114	853
	Surveyed control	127	127	135	120	117	177	803
Total		274	293	296	256	246	291	1656

2-12

Field trips concentrated upon :

- Attitudes
- Stress effects
- Nutrition
- Iodine prophylaxis
- Haematological status
- Lead poisoning
- Growth parameters
- Thyroid function
- Thyroid structure
- Past medical history
- General physical examination
- Limited cytogenetics

R-13

Prevalence of Thyroid Nodules by Age and Settlement Type*

Age, y	Contaminated Settlement No. (%)	Control Settlement No. (%)
5		
Nodule palpated	0 (0)	1 (0.8)
Nodule on sonogram	1 (0.6)	0 (0)
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60		
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Nodule on sonogram	22 (17.9)	21 (19.0)

(FA Mettler et al; JAMA 1992)

5-14

Ultrasonographic Characteristics of Discrete Thyroid Nodules in Subjects From Highly Contaminated and Control Settlements

	Simple Cyst	Complex Cyst	Hypoechoic	Isoechoic	Hyperechoic	Diameter, mm Mean (SD)
Highly contaminated settlements, No. (%) (n=45)	0 (0)	12 (27)	25 (56)	6 (13)	2 (4)	11 (7)
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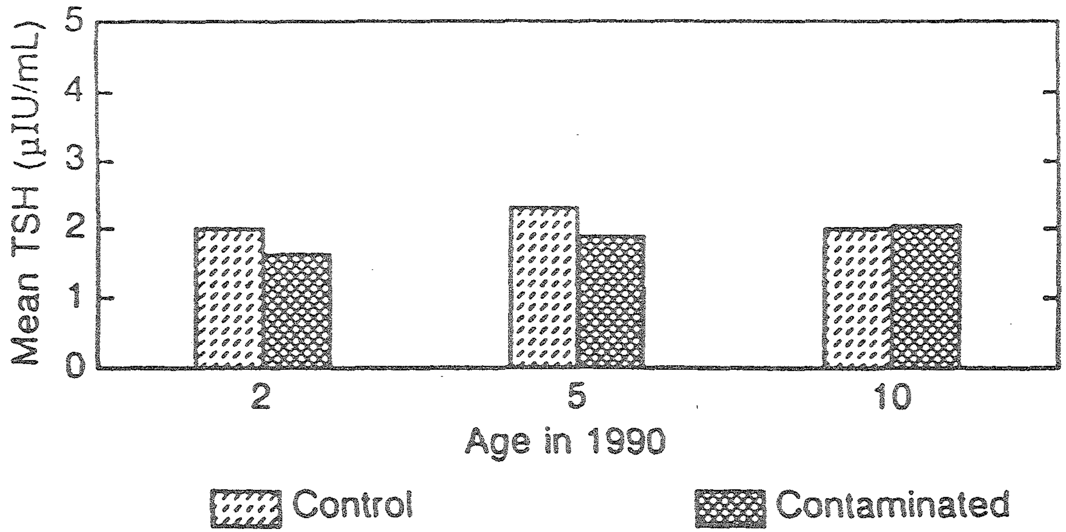
(FA Mettler et al; JAMA 1992)

2-15



Mean thyroid stimulating hormone (TSH) in children of control and contaminated settlements. µIU stands for micro-International Unit (see text). Normal range: 0.6–5.0 µIU.

S-16

- V.S.Kazakov et al : Thyroid cancer after Chernobyl, Nature 396, 1992

TABLE 1 Incidence of thyroid cancer in children in Belarus

Region of Belarus	Years 1986	1987	1988	1989	1990	1991	1992*	Total
Brest	0	0	1	1	6	5	5	18
Vitebsk	0	0	0	0	1	3	0	4
Gomel	1	2	1	2	14	38	13	71
Grodno	1	1	1	2	0	2	6	13
Minsk	0	1	1	1	1	4	4	12
Mogilev	0	0	0	0	2	1	1	4
Minsk City	0	0	1	0	5	2	1	9
Total	2	4	5	6	29	55	30	131

* Six months of 1992.

- K.Beverstock et al : Thyroid cancer after Chernobyl, Nature 359, 1992

S-17

Counterarguments

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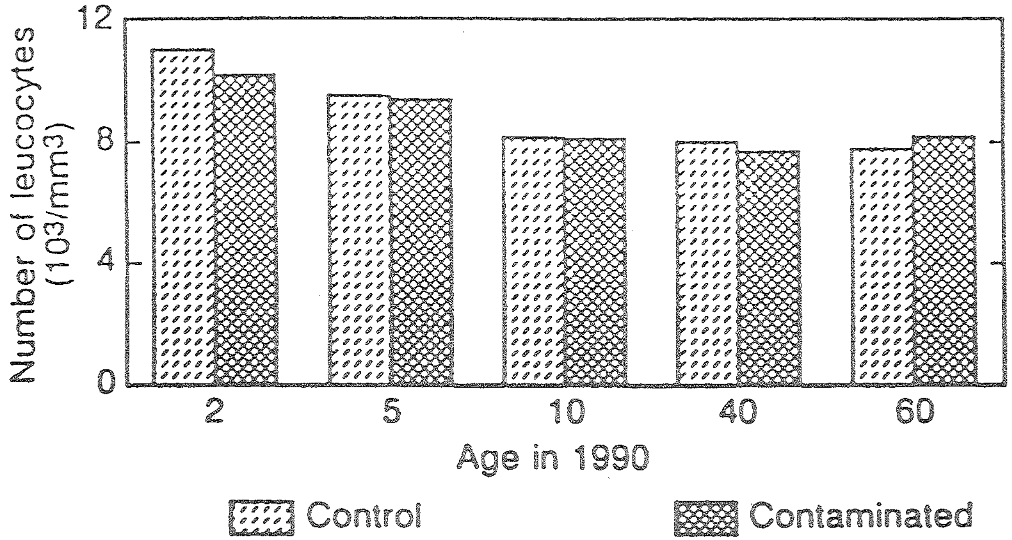
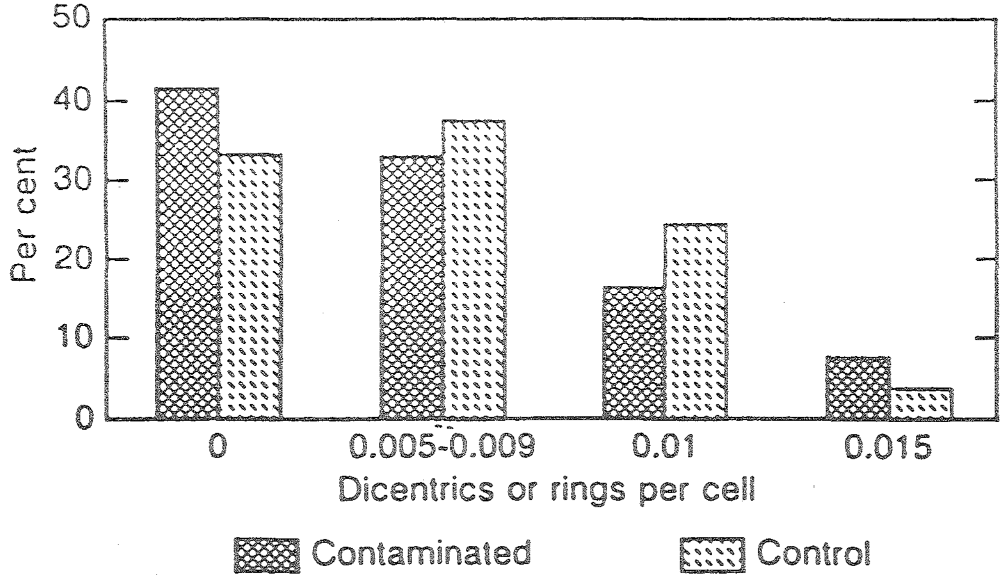
- E.Ron : Thyroid cancer incidence, Nature 360, 1992

P-18



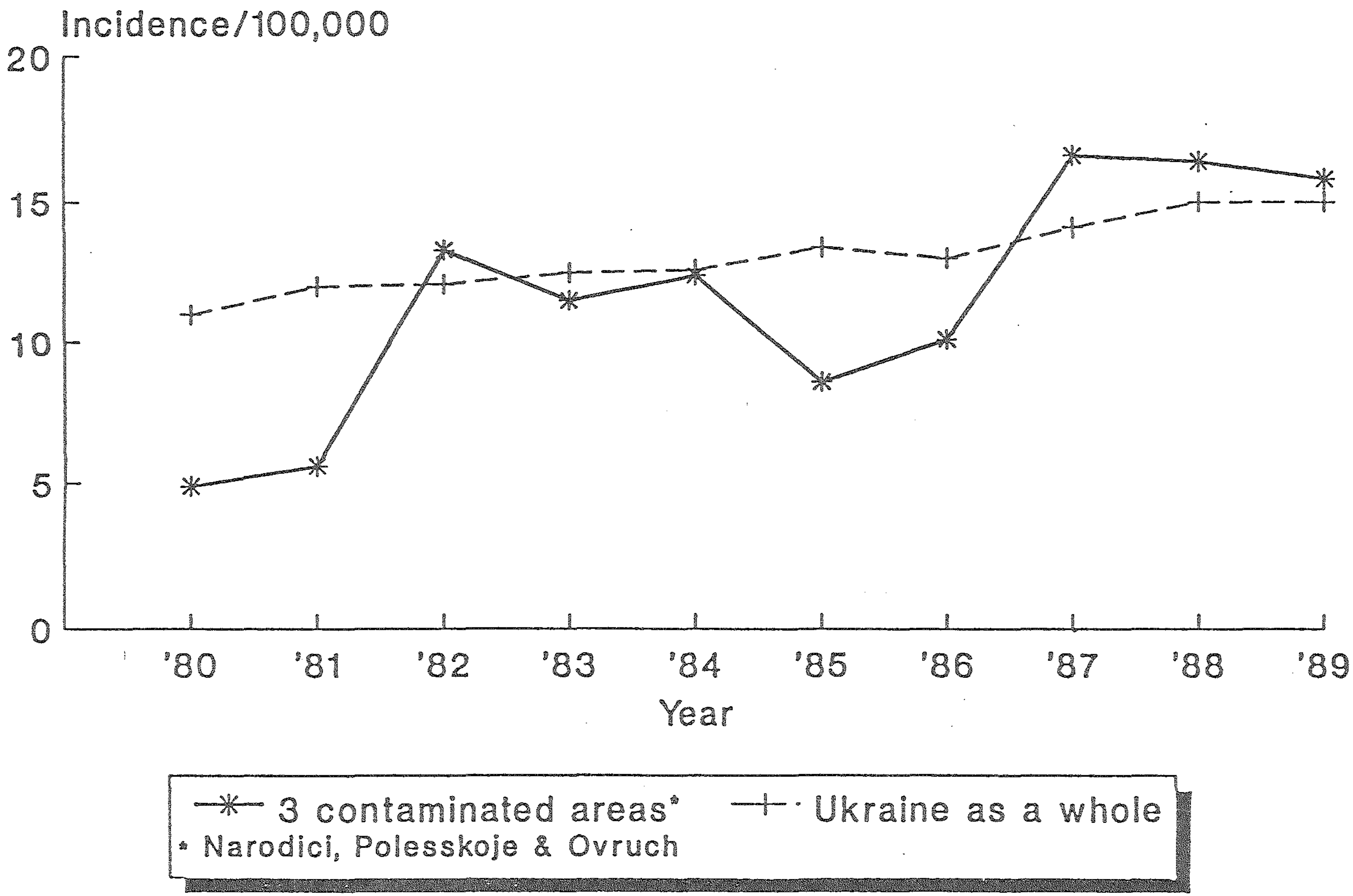
Mean leukocyte count by age in control and contaminated settlements.

P-19



Cytogenetic data: per cent of dicentrics or rings per cell.

Incidence of Hematopoietic Malignancies
Ukraine Tumor Registry Data



S-20

S-21

European Childhood Leukaemia-Lymphoma Incidence Study

	Bascline(1980-1985)		Observed(1987-1988)		Expected(1987-1988)*
	Cases	Cumulative rate	Cases	Cumulative rate	Cases
Austria	374	657	52+	588+	58.4
Finland	285	745	81	638	94.7
Italy	244	714	60	669	63.7
Poland	1431	350	516	396	498.9
ex-USSR	235	514	79	493	82.1

* Based on age-specific incidence 1980-1985.
+ 1987 data only.

(Eur J Cancer, 29A, 1993)

S-22

ミンスクのイワノフ博士が発表した
白血病と造血器障害の発生頻度
（1979-82，1983-85は、いずれも年間平均の数）

	1979-82	1983-85	1986	1987	1988
【ゴメリ地域】					
慢性骨髄性白血病	21	17	15	18	40
慢性リンパ性白血病	49	44	45	45	97
骨　髄　腫	15	16	17	28	26
再生不良性貧血病	11	13	14	10	21
【モギリョフ地域】					
慢性リンパ性白血病	55	49	43	78	65

（読売新聞 1992. 7. 2.付）

ベラルーシ共和国における小児白血病および甲状腺ガン
ーーチェルノブイリ原子力発電所事故後6年後の状況

ベラルーシ保健省血液学輸血学研究所所長
E．P．イワノフ

チェルノブイリ原子力発電所事故の結果、５０００万キュリー（Ｃｉ）を超えるさまざまな放射性核種が大気中に放出された。事故後の最初の２週間の間に放出された主な放射性核種は、ヨウ素１３１（I^{131}）、セシウム１３４（Cs^{134}）、セシウム１３７（Cs^{137}）であり、チェルノブイリ原子力発電所から半径３０ｋｍ以内にある地域では、これにストロンチウム９０（Sr^{90}）、プルトニウム２３９（Pu^{239}）およびプルトニウム２４０（Pu^{240}）が加わる。

全体的に見て、ベラルーシにおける放射能による汚染の程度と規模は、ロシアやウクライナにおけるそれを大幅に上回っている。ベラルーシにおける汚染地域は７０００km^2に達し（ちなみに、ウクライナは１０００km^2で、ロシア共和国は２０００km^2）、６州のうちの５州にある２７の町と２６９７の村、ベラルーシの人口の５分の１に相当する２５０万人が影響を受けた。この中には４４万人の子供が含まれている。事故後５年間、１万２０００人の子供が汚染の割合が１５～４０Ｃｉ／km^2の地域に、また、１０万２０００人の子供が５～１５Ｃｉ／km^2の地域に、残りが１～５Ｃｉ／km^2の地域に居住していた。すなわち、全体としての計算上の被曝線量は、それぞれ５～６および２．５～３．５ レムに相当する。

事故後のベラルーシの全国民の組織線量および体内に蓄積された放射性のCs^{137}とSr^{90}の量は数倍に増加している。このように、Sr^{90}の生体組織への蓄積は、事故前のレベルと比較して２．５～５倍に増加している。それぞれの汚染地区における１人あたりの生涯骨髄線量は、ベラルーシが８．８ミリシーベルト（ｍＳｖ）、ウクライナが２．８ｍＳｖ、ロシアが１．０ｍＳｖになると予測される。Cs^{137}の汚染の割合が４０Ｃｉ／km^2の地域では、１９８６年～８８年にかけての骨髄線量が６２ｍＳｖに達した。ちなみに、通常の放射線バックグラウンドでは、年平均の骨髄線量は１．１２ｍＳｖである。

チェルノブイリ事故の医学的な影響としては、白血病を含む放射線に起因するガン、出産障害、遺伝子的影響の３つが主なものとして予測される。表-１には、被曝後５０年間の放射線被曝により引き起こされる甲状腺ガンおよび白血病の発生率の予測が示されている。また、表-２のデータからは、すでに１９８９年～９０年においては、実際の子供の甲状腺ガンの発生率が計算上の（予測）増加率に達していることがうかがえる。

白血病は全身被曝に続いてあらわれる放射線起因のガンの一形態であり、骨髄は最も敏感な生体組織の１つであることから、白血病は、チェルノブイリ事故のあらゆる全ての発

ガン影響の蓋然的影響度の初期指標としての役割を果たすことができる。

ベラルーシでは、悪性血腫の特別の登録制度が確立されてきた。このデータは、全６州の血液担当部局や腫瘍センター、検屍解剖や死亡説明書など、ありとあらゆる情報源から集められた。ベラルーシの人口は１０５０万人で、そのうち２３０万人が０～１４歳までの子供である。各州について、Cs^{137}による放射性核種の汚染度別の居住地区の数が図-１に示されている（図の左側の目盛りを参照）。全人口のうち、２２０万人（この中には０～１４歳の子供４０万人が含まれる）がCs^{137}の汚染度が１５～３９Ci／km^2の地域に居住しており、１万２０００人が４０Ci／km^2以上の汚染度の地域に居住している。人口１００万人あたりの小児白血病の発生者数とセシウム１３７による放射性核種の汚染度との対比が図-１に示されている（図の右側の目盛り参照）（１９９０年の値）

表-３には、チェルノブイリ事故前後のベラルーシにおける人口１００万人あたりの小児白血病（急性および慢性）の発生率が各州別に示されている。各州は、Cs^{137}の汚染度により測定された放射線被曝のレベルによって分類されている。ここで目を引くことは、子供達の中にチェルノブイリ事故を原因とする白血病発生の統計学上有為な増加が見あたらないということである。

また、表-４にはチェルノブイリ事故前・後のベラルーシにおける１００万人あたりの急性小児白血病の発生件数が示されている。この表に示された結果も上述した見解を裏打ちするものとなっている。

さらに、ここでわれわれが最も被曝量が多い２つの州に注目したとすれば、チェルノブイリ事故後５年間、１９８６年から１９９０年にかけて急性白血病の発生について有為な変化はないということは疑いようがない。より具体的にいえば、０歳から５歳にかけての子供の白血病がわずかに増加したことが推測されるにすぎないのである。

１９７９～８５年の期間におけるベラルーシの小児白血病の発生率は、１００万人につき４２人の割合だった。チェルノブイリ事故後６年間（１９８６～９１年）のベラルーシにおける小児白血病の発生率は、実際には変化はない。すなわち、１９７９～８５年および１９８６～９１年の期間の子供１００万人中の小児白血病の発生率は、ゴメリ州でそれぞれ３５±３．５人と４０±４．９人、モギレフ州で４８±４．９人と４１±４．８人であるのに対し、統計学上の対照群であるビテプスク州では３９±４．１人と４２±４．５人だった。また、これにより、チェルノブイリ事故後の期間においても、ベラルーシでは明確な小児白血病の発生率の増加がないことが示された。もし、ここで我々がベラルーシにおける小児白血病のデータと欧州諸国におけるデータを比べてみたとしたら、この結論は一層確かなものとなろう。［５］（図-２参照）

しかしながら、上述した骨髄に対する放射線被曝のデータは非常に印象的である。これらのデータを前にし、我々はこれに対する一層の調査を行わねばならない。また、これと同時に、小児白血病の発生率の最近の変動は、放射性核種の汚染による骨髄被曝線量のレ

ベルとは関連しておらず、他の白血病の誘発要因（例えば化学物質など）の作用によるものであろうと結論づけられるだろう。（表-5）

図－１

Ｃｓ¹³⁷の放射性核種により汚染された州の居住地区数および小児白血病の発生率（１９９０年）

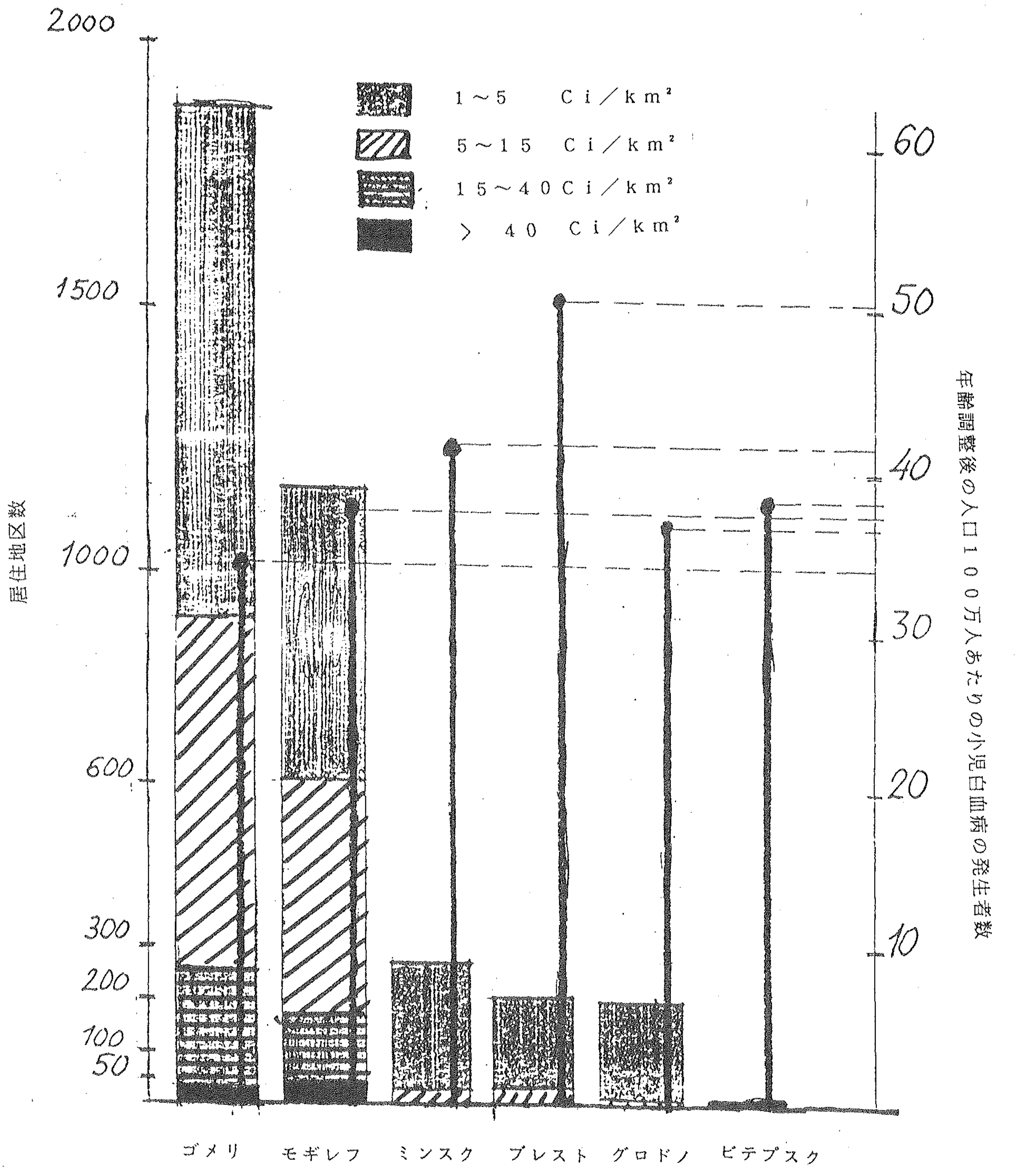
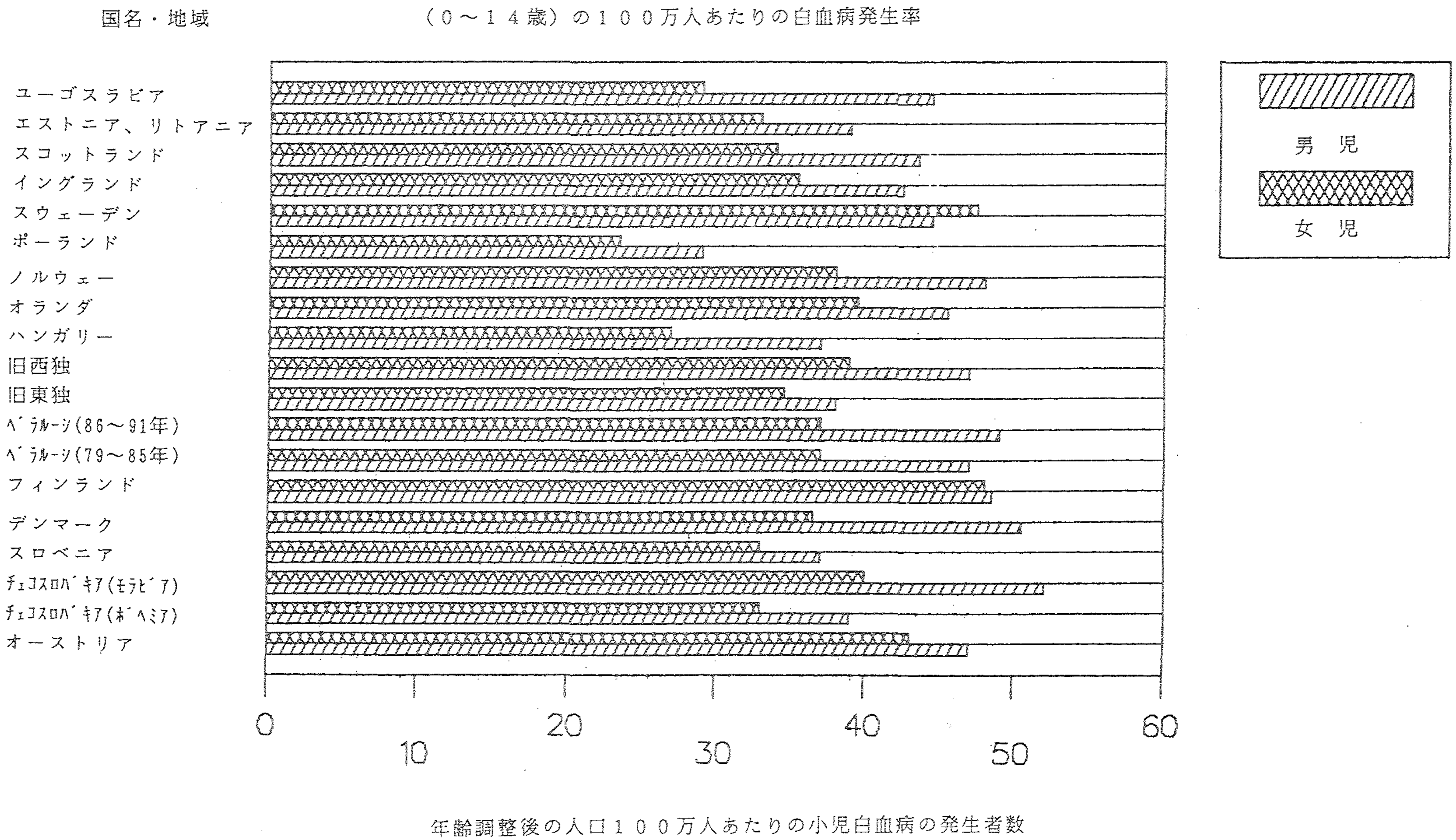


図 — 2

欧州（１９８０～８５年）とベラルーシ（１９７９～９１年）における子供（０～１４歳）の１００万人あたりの白血病発生率



表－1　ベラルーシにおけるチェルノブイリ事故を原因とした白血病および甲状腺ガンの予測される追加発生の見通し

I^{131}の被曝による集団実効線量当量		甲状腺ガンの追加発生件数（５０年間）		放射線被曝による集団実効線量当量	白血病の追加発生件数（５０年）	
成人 (1.34 million)	子供 (160000)	成人	子供	10 000 000	成人	子供
363140 men-Sv	81760 men-Sv	10894	2453	280000 men-Sv	18550	7450

表－２　ベラルーシにおける子供の甲状腺ガンの発生

ベラルーシの地域（州）	年							
	1986	1987	1988	1989	1990	1991	1992*	合計
ブレスト	0	0	1	1	6	5	5	18
ビテプスク	0	0	0	0	1	3	0	4
ゴメリ	1	2	1	2	14	38	13	71
グロドノ	1	1	1	2	0	2	6	13
ミンスク	0	1	1	1	1	4	4	12
モギレフ	0	0	0	0	2	1	1	2
ミンスク市	0	0	1	0	5	2	1	9
全ベラルーシ	2	4	5	6	29	55	30	131

注：*１９９２年上期（１～６月）

表－３

ベラルーシ共和国におけるチェルノブイリ事故前（１９７９～８５年）および事故後（１９８６～９１年）の１００万人あたりの急性・慢性小児白血病（０～１４歳）の発生率

サンプリング	期間	
	1979-1985	1986-1991
男児	47	49
女児	37	37
男児・女児	42	43

表－４

チェルノブイリ事故前（１９７９～８５年）、後（１９８６年～９１年）におけるベラルーシの子供（０～１４歳）の１００万人あたりの急性白血病の発生率

放射性核種による汚染の程度	州／都市名	期間	
		1979-1985	1986-1991
重　度	ゴメリ モギレフ	35±3,5 $\bar{x}$=41,5±4,2 48±4,9	40±4,9 $\bar{x}$=40,5±4,8 41±4,8
中　度	ブレスト ミンスク市 ミンスク	41 51　x=42,3 35	40 48　x=42,7 40
低　度	グロドノ ビテプスク	36±3,2 $\bar{x}$=37,5±3,6 39±4,1	38±2,9 $\bar{x}$=40,0±3,7 42±4,5

表－５

チェルノブイリ事故前（１９７９～８５年）、後（１９８６年～９１年）におけるベラルーシの子供（０～１４歳）の１００万人あたりの小児白血病の発生率

	期間		合計		
	1979-1985	1986-1991	1979-1991	放射性核種による汚染の程度	大気の化学汚染（トン／ｋｍ²／年）
ブレスト	41	40	196	+	2.8
ビテプスク	39	42	145	0	10.4
ゴメリ	35	40	192	+++	4.6
グロドノ	36	38	132	+	3.2
ミンスク	35	40	190	+	2.2
モギレフ	48	41	174	++	7.6
ミンスク市	51	48	218	0	735.4
ベラルーシ全体	40.7	41.3	1247		

E.P. IVANOV, Minsk, Belarus

CHILDHOOD LEUKAEMIA AND THYROID CANCER IN BELARUS - SIX YEARS AFTER THE CHERNOBYL ACCIDENT

As a result of the Chernobyl accident over 50 million Curie of various radionuclides were thrown in to the atmosphere. During the first two weeks after the accident the main ionizing radionuclides were I^{131}, Cs^{134} and Cs^{137}, and in 30-kilometre radial zone Sr^{90}, Pu^{239} and Pu^{240}.

On the whole the degree and scale of radioactive contamination in Belarus greatly surpassed those in Russia and the Ukraine The contaminated territory in Belarus is equal to 7 thousand sq. km /cf: 1000 in the Ukraine and 2000 in Russia/. 27 towns and 2697 villages in five out of the six regions with up to 2.5 million population / one-fifth of the republic population/ were affected, including 440 000 children. During the five years after the accident 12 000 children inhabited the territories with the contamination rate of 40 to 15 Ci/sq.km , 102 000 with that of 15 to 5 Ci/sq.km and the rest with that of 5 to 1 Ci/sq.km; the calculated doses of the overall irradiation are equal to 5-6 and 2.5-3.5 ber respectively.

Post-accident tissue doses of Belarus population and the incorporated radioactive Cs^{137} and Sr^{90} content in tissues have increased several times. Thus, Sr^{90} content in tissues have increased 2.5-5 times in comparison with the preaccidential level. Lifetime bone marrow doses per person are expected as 8.8 mSv in Belarus, 2.3 and 1.0 mSv in the Ukraine and Russia, in the cotaminated areas respectively. At the contamination rate for Cs^{137} equal to 40 Ci/sq.km the bone marrow dose in 1986-88 reached 62 mSv /with normal radiation background the mean annual dose for red bone marrow is 1.12 mSv/.

Asto the medical consequences of the catastrophe three major are supposed to be anticipated in persons exposed to radiation-cancer, including leukaemia, birth defects and genetic abnormalities. Table 1 shows the forecasted thyroid cancer and leukaemia incidence rate induced by radiation in the next 50 years. The data in table 2 show that alredy in 1989-90 the real thyroid cancer incidence rate in children reached the calculated rate /Kazakov et al, 1992/

Since leukaemia is the second form of radiogenic cancer to appear following whole-body exposure and bone marrow is one of the most sensitive tissues, it can serve as an early indicator of the probable magnitude of any overall carcinogenic effect of the Chernobyl accident.

In the republic of Belarus the special register of blood malignancies has been established. The data were collected from all possible sources, i.e. hematological departments in all 6

Table 2.

Incidence of thyroid cancer in children of Belarus

REGION OF BELARUS	YEARS							
	1986	1987	1988	1989	1990	1991	1992 *	TOTAL
Brest	0	0	1	1	6	5	5	18
Vitebsk	0	0	0	0	1	3	0	4
Gomel	1	2	1	2	14	38	13	71
Grodno	1	1	1	2	0	2	6	13
Minsk	0	1	1	1	1	4	4	12
Mogilev	0	0	0	0	2	1	1	4
Minsk city	0	0	1	0	5	2	1	9
Belarus	2	4	5	6	29	55	30	131

Note: * – 6 months of 1992

Table 3

Incidence rate of childhood (0-14 years of age) acute and chronical leukemia in the Republic of Belarus in toto per million before (1979-1985) and after (1986-1991) the Chernobyl disaster

sampling	period of time	
	1979-1985	1986-1991
Boys	47	49
Girls	37	37
Both boys and girls	42	43

oblasts (regions) of the republic, oncological centers, autopsies, death certificates etc. The population of the republic is 10.5 million residents including 2.3 million of children of 0-14 years of age. The distribution of the settlements per oblast vs value of Cs_{137} density of radionulides contamination is presented in Figure 1 (data featured in the left-hand margin). Among the whole population 2.2 million (including 400 thousand children of 0-14 years of age) live in the contaminated areas with density of Cs_{137} in the range of 15 - 39 Ci per square km, 12 thousand — with 40 and more Ci per square km. The distribution of the incidence rate of childhood leukemia per million vs value of Cs_{137} density of radionuclides contamination is presented in Figure 1 (right-hand margin) (on 1990 year).

Table 3 plots the incidence rate of childhood leukemia in the Republic of Belarus per million vs oblast before and after the Chernobyl disaster. The oblasts are grouped with the accordance of the level of ionizing radiation exposure measured by density of Cs_{137}. It is noticeable that no statistically significant increase of leukemia incidence among children caused by the Chernobyl disaster is visible.

Table 4 plots the incidence rate of childhood leukemia in Belarus in toto before and after the Chernobyl disaster. The results presented in the table support the same idea.

Moreover, if we concentrate our attention only on two most highly exposed oblasts, it would be undoubtedly estimated that during 5 years after the Chernobyl accident there were no significant changes in acute leukemia incidence in 1986-1990. To be more concrete, it was estimated only some minor increase in leukemias in children of 0-5 years of age.

The in toto incidence rate of childhood leukemia in Belarus in the period of 1979-1985 was 42 per million. During the 6 years after the accident (1986-1991) childhood leukemia incidence rate

Table 1.

PROGNOSIS OF forecasted EXCESS LEUKAEMIA AND THYROID CANCER IN BYELARUS AS CONSEQUENCES OF THE CHERNOBYL ACCIDENT

COLLECTIVE EFFICIENT DOSE OF EXPOSURE TO I 131 RADIATION		NUMBER OF EXCESS THYROID CANCERS (50 years)		COLLECTIVE EFFICIENT DOSE OF EXPOSURE RADIATION	NUMBER OF EXCESS LEUKAEMIA (50 years)	
ADULTS (1.34 million)	CHILDREN (160 000)	ADULTS	CHILDREN	10 000 000	ADULTS	CHILDREN
363 140 men-Sv	81 760 men-Sv	10 894	2453	280 000 men-Sv	18 550	7450

Table 4

Incidence rate of Acute Leukaemias in Byelorussian Children (age 0-14) per million before (1979-1985) and after (1986-1991) the Chernobyl accident

Degree of radionuclide contamination	Oblast/City	Period of time	
		1979-1985	1986-1991
Severe	Gomel Mogilev	35±3,5 $\bar{x}$=41,5±4,2 48±4,9	40±4,9 $\bar{x}$=40,5±4,8 41±4,8
Middle	Brest Minsk City Minsk	41 51 x=42,3 35	40 48 x=42,7 40
Least	Grodno Vitebsk	36±3,2 $\bar{x}$=37,5±3,6 39±4,1	38±2,9 $\bar{x}$=40,0±3,7 42±4,5

in Belarus practically has not changed and comprised: for Gomel oblast (in 1979-1985 and 1986-1991 accordingly) 35 ± 3.5 and 40 ± 4.9, for Mogilev oblast: 48 ± 4.9 and 41 ± 4.8, for Vitebsk olast (control region): 39 ± 4.1 and 42 ± 4.5 per million children. Again it shows no proved increase in childhood leukemia rate in Belarus in post-Chernobyl period. The conclusion occurs to be still more grounded if we take into account the data on childhood leukemia in Belarus as compared with that of Europe [5] (Figure 2).

However, the data on radiation exposure of bone marrow that were mentioned above, are much impressive. These data provoke us to fulfill the further corresponding investigations. At the same time it might be concluded that recent variations in the incidence rate of childhood leukemia are not connected with the level of radionulides contamination bone marrow exposure dose and may be attributed to action of another leukemiageneous factors (e.g., the chemical ones) (Table 5).

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Prof. Eugene Ivanov

Figure 1

THE NUMBER OF POPULATED LOCALITIES, CONTAMINATED WITH RADIONUCLIDES WITH DENSITY OF Cs_{137} AND INCIDENCE RATE OF CHILDHOOD LEUKAEMIA

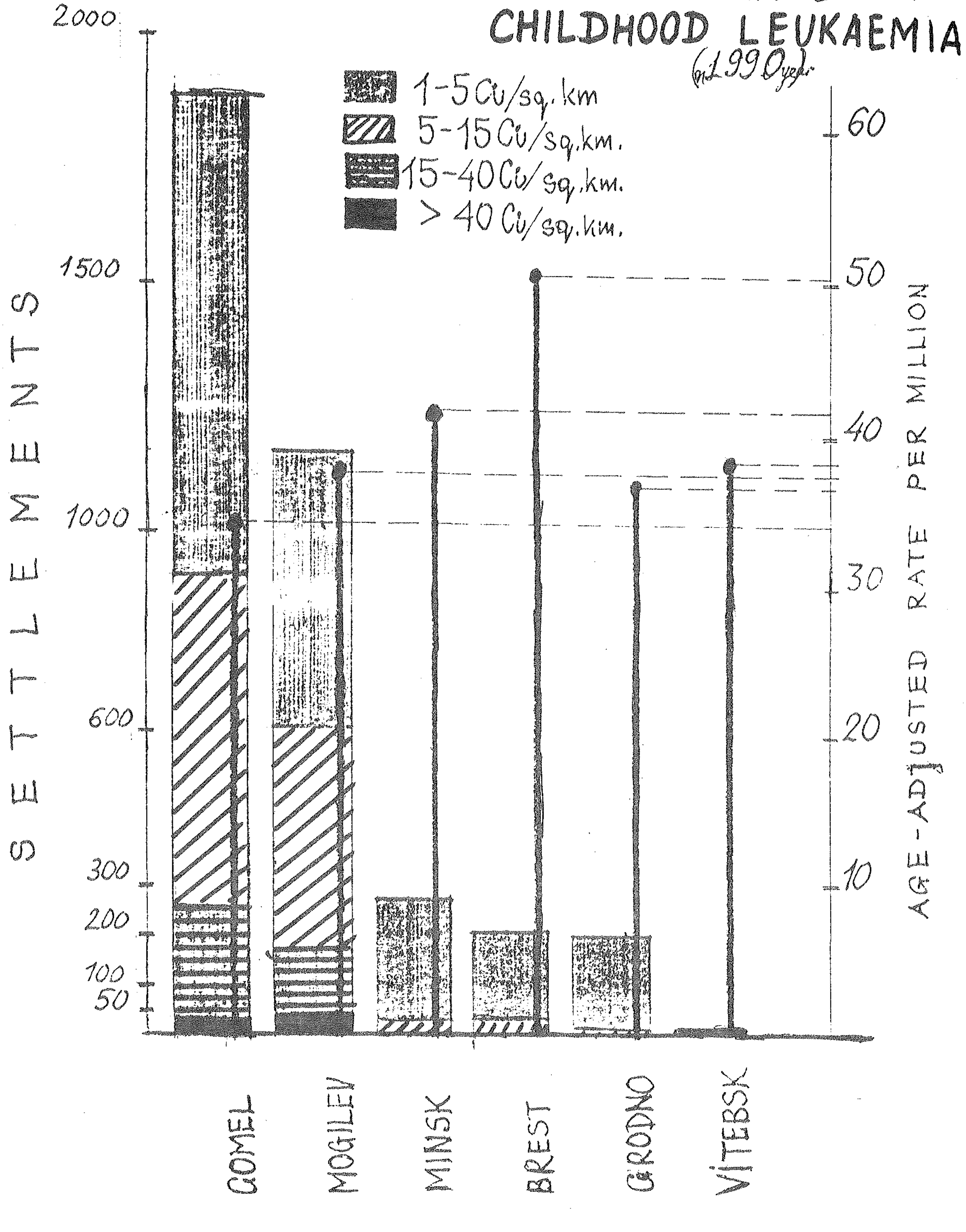

Figure 2

Leukaemia among children(0–14years) in Europe(80–85) and Belarus(79–91)

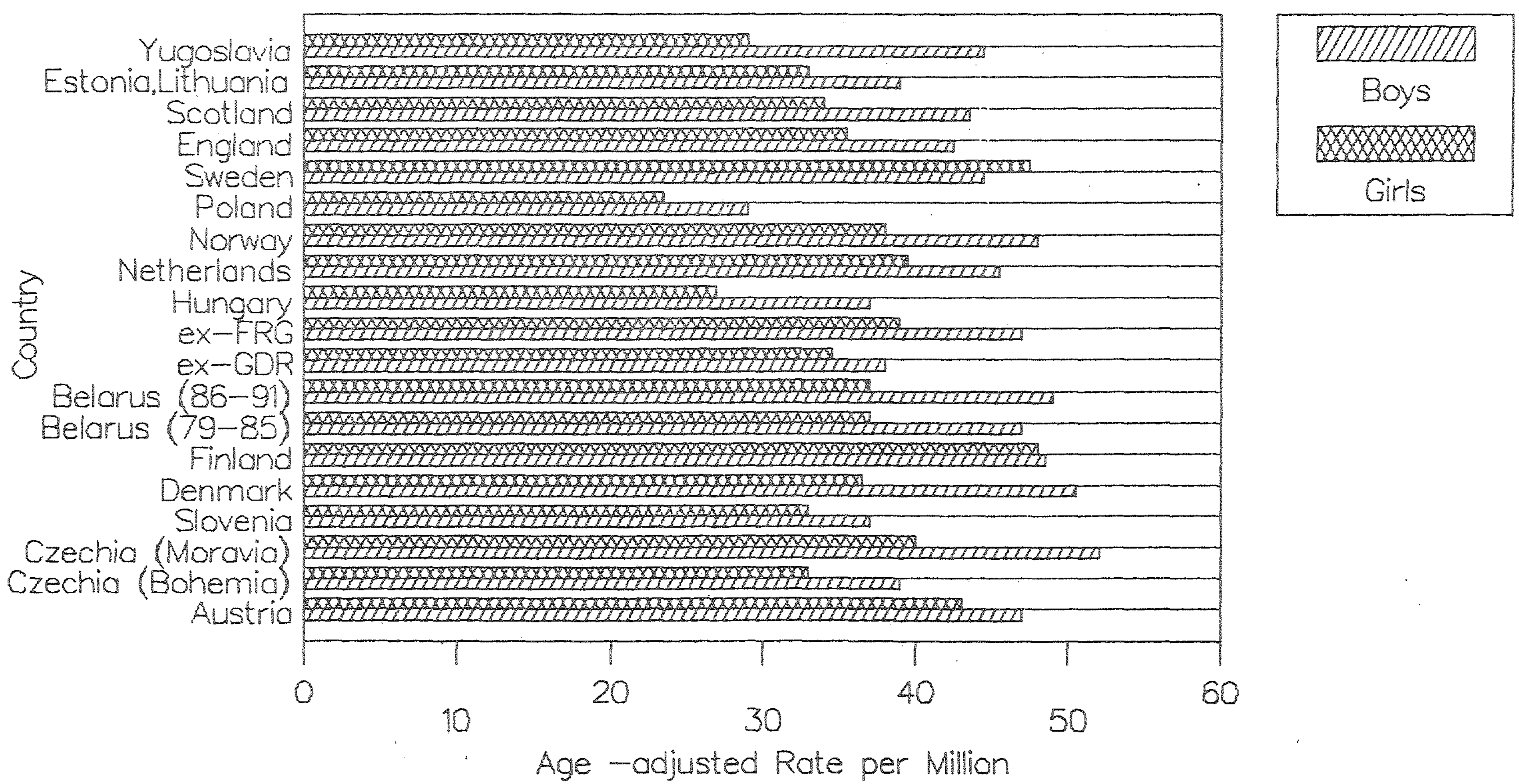

Table 5.

INCIDENCE OF CHILDHOOD LEUKAEMIA /AGE 0-14/ IN BELARUS

PER 1 MLN. CHILDREN IN 1979-1991

Region / City	Years 1979-1985	Years 1986-1991	Total 1979-1991	Degree of radionuclide contamination	Chemical pollution of the air ton/sq.km per year
BREST	41	40	196	+	2.8
VITEBSK	39	42	145	0	10.4
GOMEL	35	40	192	+++	4.6
GRODNO	36	38	132	+	3.2
MINSK	35	40	190	+	2.2
MOGILOV	48	41	174	++	7.6
MINSK CITY	51	48	218	0	735.4
BELARUS REPUBLIC	40.7	41.3	1247		

チェルノブイリ原子力発電所事故の影響を受けた地域に居住する住民の健康影響

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１９８６年４月に発生したチェルノブイリ原子力発電所事故の結果、短期間のうちに、これまで原子力発電所で記録された中では、最も大量の放射性物質が大気中に放出された。この事故の人間に対する影響は多大であり、事故から６年以上たった今でも、依然として、チェルノブイリ原子力発電所の周辺地域に居住している住民の健康に対するもっともらしい被曝影響についての情報はほとんどない。

１９８９年１０月、旧ソ連の政府は国際原子力機関（ＩＡＥＡ）に対して、同事故の影響についてのアドバイスをするように要請した。ＩＡＥＡによる調査の一環として、独立の国際医学チームによる健康調査が実施された。この調査は、チェルノブイリ原子力発電所から３０ｋｍの立入禁止区域の外にある７つの“汚染居住地区”および６つの“対照居住地区”に住む１６５８人の住民を対象に行われた。いずれの地区でも、各住民が彼らの出生年別に選び出され、サンプリングは若年層とチェルノブイリ事故当時にまだ生まれていなかった者にウエイトがかけて行われた。各項目ごとに質問表が作成され、身体検査、血液検査、甲状腺検査等が実施された。これらのデータの分析では、汚染地域の子供のうち有意に高い割合で、食欲不振や甲状腺異常、貧血症などが報告されていることが示されている（ＩＡＥＡ、１９９１年）。しかしながら、医学検査やヘモグロビン・レベルでの血液検査、超音波診断装置による甲状腺検査の結果では、汚染地区と対象地区の間で差異はなかった。それゆえ、人々の子供の将来の生活や健康に対する不安以外、健康に対する悪影響は実証されなかった。

しかしながら、この調査が制限されたものであることは強調されなくてはならないだろう。現地調査は比較的少数の住民についてのものに過ぎず、汚染地域から疎開した住民は考慮されていない。それと同時に、汚染地区と対照地区の間で一般の症例に関する統計上の差異を確認するほど大きくても、ガンやその他の希であるが重大な病気の緩やかな増加を検知するには小さすぎる。

日本における原爆の被爆者の追跡調査では、主要な長期の健康への悪影響はガンであり、ガンの発生率の変化は長期間のレンジでのみ特定できることが明らかになっている。汚染地域におけるガンの発生率に関する調査を行う一つの方法としては、ガンの登録データに注目する方法がある。ウクライナにおいては、ガンの登録データはすでに特別調査を実施するのに使われており、最も汚染された地域からの結果が出版されている(Prisyazhiuk et al,1991)。１９８１年から１９９０年までの１０年間のウクライナの３つの最も汚染が深刻な地方における白血病や甲状腺ガンおよびその他全てのガンの年齢別の発生率に関す

る調査では、ほとんどのガンについて、発生率が１９８６年の前後で概して同じである（ほとんど変化がない）ことが明らかになっている。しかしながら３つの例外がある。すなわち、１９８７年に観察された６５歳＋の年齢における白血病の発生率が事故前のレベルの２～３倍に急激に増加している；１９８１年～８９年の間、０歳～１４歳の年齢で甲状腺ガンは１件もなかったが、１９９０年に３件の症例が見られた；１９８７年に年齢６５歳＋におけるその他全てのガンの発生率が約３分の１上昇し、それ以来、このレベルが続いている。

白血病の場合、および、白血病と甲状腺ガンを除く他の全てのガンの場合において、（発生率）増加のタイミングとこれらのガンが６５歳＋のグループに集中しているという事実は、これらが放射線による直接の結果ではありそうにもないことを示唆している。一つの可能性として、事故後、年輩の患者に対して徹底的なガンの検査が行われた結果によるガンの発見者数の増加ということが考えられる。

１０万人あたりで見て、１９８１年～１９８９年がゼロ、１９９０年が１１人という観察された子供の甲状腺ガンの発生率増加を解釈することは一層難しい。汚染地域の子供は甲状腺にかなりの線量の放射線を受けており、放射線誘発による甲状腺ガンの潜伏期間についてははっきり分かってはいないものの、この年齢のグループでは甲状腺ガンが他のガンよりも著しく増加すると予測されてきた。ヨウ素１３１による汚染は３つの最も汚染が深刻な地域に限ったものではなく、公式の統計でも、ウクライナの他の地域における年齢０歳～１４歳の甲状腺ガンの発生率が、１９８９年の１０万人あたり０．０８人（９件）から１９９０年には０．１５人（１７件）と倍増したことが示されている。小児甲状腺ガンの同様な増加は、ベラルーシのいくつかの地域でも報告されてきている。この増加は１９９０年に始まり、現在も続いている。(Kazakov et al, 1992)

甲状腺ガンに関する知見の解釈は、スクリーニングの影響のためかなり複雑なものとなっている。というのは、このやり方で見つかる甲状腺ガンの多くは多分に“肉眼では見えない（隠れた）もの”であり、それ自体は決して症候的な病気に進行しないからである (Beral and Reeves,1992; Shigematsu and Thilessen, 1992; Ron et al, 1992)。これらの理由から、甲状腺ガンの発生率の増加は、とくに汚染地域の子供については、医学調査が増加したという見地から解釈される必要がある。

利用可能な情報は少ないが、ガンの発生率に関する統計は、甲状腺ガンについて例外の可能性はあるものの、チェルノブイリ原子力発電所事故を原因とするガンの増加はまだ起きていないことを示唆している。しかしながら、最も重要な点は、多くの放射線誘発ガンの発生が明らかになる以前から、ガン発生率のデータの収集が続けられることである。傾向の変化を監視し続けることで、子供の甲状腺ガンに関する状況が、数年のうちにも明らかにされるに違いない。

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Effects of the Chernobyl nuclear disaster on the health of the populations living in the affected areas

The accident at Chernobyl in April 1986 resulted in the largest short term release of radioactive materials to the atmosphere ever recorded from a nuclear plant. The human impact of the accident has been immense and, more than six years after the event, there is still little information about the likely effects of this exposure on the health of the population living in the areas surrounding Chernobyl.

In October 1989, the former USSR parliament invited the International Atomic Energy Agency to advise on the consequences of the accident. As part of their investigations, a health survey was conducted by an independent international medical team, on 1658 people still living in 7 "contaminated" and 6 "control" settlements, all of which were located outside of the 30km exclusion zone. Within each settlement, individuals were selected according to their year of birth; sampling was weighted towards the young and those who were unborn at the time of the accident. A questionnaire was completed for each subject and a physical examination and haematological and thyroid tests were performed. Analysis of these data showed that a significantly higher proportion of children in the contaminated areas were reported to be suffering from loss of appetite, thyroid abnormalities and anaemia (IAEA, 1991). Results of medical examinations and blood tests such as haemoglobin levels and ultrasound measurements of the thyroid, however, did not differ between contaminated and control regions. Therefore, no adverse health effects could be demonstrated other than people's concern for their future well-being.

It should be noted, however, that this study has limitations. The survey was only of a relatively small number of people, takes no account of those who have been evacuated from the area and while big enough to identify major discrepancies between contaminated and control settlements in the prevalence of common disorders, is too small to detect a moderate increase in cancers or other rare, but serious, disorders.

Studies of the atomic bomb survivors in Japan have shown that the main, long-term adverse effect is on cancer, and changes in incidence may only be detected over a long period of time. One way to study cancer incidence in contaminated areas is to focus on cancer registry data. In the Ukraine, cancer registry data have already been used to carry out special studies and results from the most contaminated areas have been published (Prisyazhiuk et al, 1991). Examination of the age-specific incidence rates for leukaemia, thyroid cancer and all other cancers during the 10 years 1981-1990 in the three most contaminated districts of the Ukraine show that, for most cancers, incidence was broadly similar before and after 1986. There are, however, three exceptions: in 1987, the observed incidence of leukaemia at ages 65+ rose abruptly to 2-3 times the pre-accident levels; there were no diagnoses of thyroid cancer at age 0-14 during 1981-89 but 3 cases were diagnosed in 1990; and the incidence of all other cancers at age 65+ increased by about one third in 1987 and have remained at that level since.

In the case of leukaemia and all cancers except leukaemia and thyroid cancer, the timing of the increases and the fact that they are concentrated in the 65+ age group suggest that they are unlikely to be a direct result of radiation. One possibility is that these increases are a result of more thorough investigation of elderly patients for cancer following the accident.

The increase in observed incidence of thyroid cancer in children, from zero in 1981-1989 to 11 per 100,000 in 1990, is more difficult to interpret. Children in contaminated areas received substantial doses of radiation to the thyroid and a more marked increase in thyroid than other cancers has been predicted for this age group, although the latency for radiation induced thyroid cancer is uncertain. Contamination from ^{131}I was not restricted to the three most contaminated regions and official statistics show that the incidence of thyroid cancer at age 0-14 in other areas of the Ukraine doubled from 0.08 per 100,000 in 1989 (9 cases) to 0.15 in 1990 (17). A similar increase in childhood thyroid cancer has also been reported in some parts of Belarus; this increase commenced in 1990 and continues (Kazakov et al, 1992).

The interpretation of the findings in relation to thyroid cancer is greatly complicated by the effect of screening because many thyroid cancers detected in this way are possibly "occult" and as such would never have progressed to symptomatic disease (Beral and Reeves, 1992; Shigematsu and Thlessen, 1992; Ron et al, 1992). For this reason, any increases in the incidence rates for thyroid cancer need to be interpreted in the light of increased medical surveillance, particularly among children in the contaminated areas.

Although little information is available, statistics on cancer incidence suggest that, with the possible exception of thyroid cancer, no large increase in cancer has yet occurred as a result of the Chernobyl accident. It is, however, of utmost importance that the collection of cancer incidence data continues since many radiation-induced cancers which might be expected to occur would not yet be apparent. Continued monitoring of trends should also clarify the situation with respect of thyroid cancer in children within the next few years.

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チェルノブイリ事故7年後のロシアにおける真の現状

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ロシア連邦では、チェルノブイリ事故後に最も影響を受けた州が４つある。すなわち、ブリヤンスク、カルーガ、ツーラおよびオリョール州である。これら以外にも、他のロシアの１０州とモルドバ共和国のいくつかの地域でフォールアウトが発生した。約５８１万７０００人の人口が住む４万７１７０ｋｍ^{2}のロシアの領土がCs^{137}により、１～１１０Ｃｉ／ｋｍ^{2}の範囲のレベルで汚染された。５月６日までには、I^{131}のレベルはCs^{137}のレベルの１０～１５倍も高かった。

事故後最初の数週間の間に、ロシアの放射能汚染地域に居住する約３万人の個人に対して、甲状腺のI^{131}の汚染が測定された。ここで得られたデータにより、推定評価と一緒に個人吸収線量も計算された。

ロシアの最も汚染された４つの地域での甲状腺の集団内部・外部線量は、１３万１０００人Ｓｖと推定された。甲状腺に対する内部線量は、年齢に大きく依存することが明らかになった。推定集団線量の約半分が７歳未満の子供のものである。異なる汚染レベルの地域における年齢別の平均線量は、１０～２２０ｃＧｙの範囲だった。いくつかのケースでは、個人線量は１０００ｃＧｙを超えていた。

ロシアの汚染地域に居住する住民の全身線量は、主としてセシウムによる体内放射線と高ガンマ線バックグラウンドによる外部被曝によって決定された。内部線量評価は、体内のCs^{137}およびCs^{134}の数多くの直接測定に基づいている。（事故後６年間で２０万件を超える測定が実施された） 同じものを基にして、推定計算も行われた。外部線量は、主として計算により確定された。これに加えて、熱蛍光線量計による直接測定結果が約１０００件ある。

評価の結果、ブリヤンスク、カルーガ、ツーラおよびオリョール州の最も汚染された１９の地方に７０年間永続的に居住した場合、蓄積される全身の集団実効線量は６００万人・ｃＳｖになることが示されている。すなわち、ブリヤンスク州の５地方では４４０万人・ｃＳｖ、カルーガ、ツーラおよびオリョール州の１４地方では１６０万人・ｃＳｖとなる。４つの最も汚染された州における事故後５年間に蓄積された全身の平均実効線量は、１～１４ｃＳｖの範囲であった。これらの地域における１９９２年の年間の平均実効線量は０．０５～０．９ｃＳｖの範囲だった。

しかしながら、各個人ごとの線量は、平均値とは大きく異なるだろう。個人に対する利用可能な測定結果に基づく推定値によると、ブリヤンスクの重度に汚染された地域では、事故後、住民の約３％について、全身線量の合計が２５ｃＳｖを超えている可能性がある

ことが示されている。ブリヤンスク州の最も汚染された地域においては、住民の１０％以上が生涯線量で３５ｃＳｖを超えるであろう。

チェルノブイリ事故後の影響を受けた人々についてのロシアの国家的な医学・線量登録制度が、医学放射線科学センターで確立された。

現時点までの登録制度のデータベースには、２３万人の医学・線量測定情報が含まれており、この中には１４万４０００人の復旧作業従事者と７万３０００人のロシアの放射能汚染地域住民が入っている。

１９８６年～８７年にかけて、放射線影響があった地域で活発に復旧作業に従事した復旧作業従事者は、甲状腺に大量の放射線を被曝した子供とともに、リスクの比較的高いグループであると考えられている。

上記のグループにおける疾病率の分析は、（単純）合計値およびいくつかの疾病分類学的形態における疾病率の増加を示している。また、これとは別に、実施された放射線疫学調査は、疾病率の増加と線量の間のいかなる相関関係も立証してはいない。チェルノブイリ事故の影響評価を行う際には、精神身体医学的な要素が極めて重要である。

SEVEN YEARS AFTER THE CHERNOBYL ACCIDENT TRUE SITUATION IN RUSSIA

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In Russian Federation there are four oblasts mostly affected after the Chernobyl accident: Bryansk, Kaluga, Tula and Orel oblasts. Besides, radioactive fallout also took place in certain locations of other ten Russian oblasts and in Mordvinian Republic. In total 47 170 sq. km. of Russian territory with population of about 5 817 000 have been contaminated with Caesium-137 at the levels ranging from 1 to 110 Ci/sq. km. By May 6 Iodine-131 levels were 10-15 times higher than the Caesium-137 ones.

During the first weeks after the accident about 30 000 individuals residing radiocontaminated areas of Russia were measured for Iodine-131 content in thyroid glands. Absorbed individual doses as well as extrapolation estimation were calculated using dat obtained.

The collective internal and external thyroid dose was estimated as 131 000 person*Sv for the four mostly contaminated regions of Russia. Strong age dependence of dose of internal radiation for thyroid gland was revealed. Approximately half of the estimated collective dose regards children before 7 years old. Mean doses for age-groups in the areas with different levels of contamination ranged from 10 to 220 cGy. In some cases individual doses were over 1 000 cGy.

Whole-body irradiation of people residing contaminated Russian areas was mainly stipulated by internal irradiation with caesium and external exposure due to higher gamma - background. Internal dose estimations were based on the large number of direct measurements for Caesium-137,134 body content (over 200 000 measurements for 6 years after the accident). On the same basis extrapolation calculations were performed. External doses were established mainly by calculations. Furthermore, there are about 1.000 results of direct measurements made by TL-dosimetry.

The results of estimation indicate that accumulated collective effective whole-body dose in case of permanent residence for 70 years in mostly contaminated 19 raions of Bryansk, Kaluga, Tula and Orel oblasts makes up 6 million person*cSv: 4.4 million person*cSv in 5 heavy contaminated raions of Bryansk oblast and 1.6 million person*cSv in 14 raions of Kaluga, Tula, Orel oblasts. For 5 years after the accident mean accumulated effective dose to the whole body in 4 mostly contaminated oblasts ranged from 1 to 14 cSv. In 1992 mean effective annual doses were in these territories in the range of 0.05-0.9 cSv.

However, individual doses may significantly differ from the mean values. Extrapolated values being based on available results of individual measurements indicate that in heavy contaminated areas of Bryansk oblast for the post-accidental period about 3% residents might receive total whole-body dose of over 25 cSv. Accumulated life-span dose for over 10% residents in mostly contaminated Bryansk areas may exceed 35 cSv.

The Russian National Medical and Dosimetric Registry of those affected after the Chernobyl accident was established on the basis of the Medical Radiological Research Centre.

By now the data base of the Registry includes medical and dosimetric information on 230.000 persons, among them there are 144.000 liquidators and 73.000 residents of the radiocontaminated areas of Russia.

Liquidators that were actively involved in the recovery measures in zones of radiation effect for the period of 1986-1987 as well as children with thyroid glands exposed to significant doses radiation are considered to be the group of the higher risk.

The analysis of the morbidity in the above groups revealed growth of indications for both disease rate in total and in certain nosological forms. Besides, the performed radiation--epidemiological investigations do not prove any dependence between increase in morbidity and dose. Psychosomatic factor is of significant importance in estimation of the consequences of the Chernobyl accident.

Editor: Mrs. I. Tikhonova

СЕМЬ ЛЕТ ПОСЛЕ ЧЕРНОБЫЛЬСКОЙ АВАРИИ. РЕАЛЬНАЯ СИТУАЦИЯ В РОССИИ.

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В Российской Федерации в результате аварии на Чернобыльской АЭС наиболее интенсивному радиоактивному загрязнению подверглись территории четырех российских областей: Брянской, Калужской, Тульской, Орловской. Кроме того, радиоактивные осадки выпали на отдельных участках еще 10 областей России, а также в Республике Мордовии. В общей сложности в России на уровне от 1 до 110 Ки/кв.км. по цезию-137 загрязнено 47170 кв.км. с населением около 5 миллионов 817 тысяч человек. Уровни загрязнения йодом-131 по состоянию на 6 мая в 10-15 раз превышали таковые по цезию-137.

В первые недели после аварии на загрязненных радионуклидами территориях России приблизительно у 30 000 человек были проведены измерения содержания йода-131 в щитовидной железе. На основании этих данных были рассчитаны индивидуальные поглощенные дозы, а также осуществлены экстраполяционные оценки.

Оценка коллективной дозы внутреннего и внешнего облучения щитовидной железы дает величину в 131 тыс. человекозиверт для четырех наиболее загрязненных областей России. Установлено наличие сильной возрастной зависимости дозы внутреннего облучения щитовидной железы. Приблизительно половина оцененной коллективной дозы приходится на детей в возрасте до 7 лет. Средние дозы в возрастных группах на территориях с разной степенью загрязненности находились в пределах от 10 до 220 сГр. В отдельных случаях величины индивидуальных доз превышали 1000 сГр.

Облучение всего тела жителей загрязненных территорий России было обусловлено, в основном внутренним облучением радионуклидами цезия, а также внешним облучением за счет повышенного гамма-фона. Оценки доз внутреннего облучения основаны на большом количестве результатов прямых измерений содержания радионуклидов цезия-137,134 в организме (свыше 200 тысяч измерений за шесть лет после аварии). На этой основе выполнены экстраполяционные расчеты. Оценки доз внешнего облучения имеют, в основном, расчетный характер. Кроме того, имеется около 1000 прямых измерений методом ТЛ дозиметрии.

Проведенные оценки показывают, что накопленная коллективная эффективная доза облучения всего тела при постоянном проживании в течении 70 лет на территории наиболее пострадавших 19 районов Брянской, Калужской, Тульской и Орловской областей составляет 6 миллионов чел.сЗв: 4,4 миллиона чел.сЗв по 5 наиболее загрязненным районам Брянской области и 1,6 миллиона чел.сЗв по 14 наиболее загрязненным районам остальных трех областей. За 5 лет после аварии средние накопленные эффективные дозы облучения всего тела для четырех наиболее загрязненных областей находятся в пределах от 1 до 14 сЗв. В 1992 году средние эффективные годовые дозы находились в пределых от 0,05 до 0,9 сЗв.

Вместе с тем, индивидуальные дозы облучения могут существенно отличаться от средних величин. Экстраполяционные оценки, основанные на имеющихся данных индивидуальных измерений, показывают, что на наиболее загрязненных территориях в Брянской области за период после аварии около 3 процентов населения могли получить суммарные дозы облучения всего тела свыше 25 сЗв. Накопленная доза за всю жизнь при проживании на наиболее загрязненных территориях Брянской области у более чем 10% населения может превысить 35 сЗв.

На базе Медицинского радиологического научного центра РАМН создан и функционирует Российский государственный медико-дозиметрический регистр лиц, подвергшихся радиационному воздействию в результате аварии на ЧАЭС.

В настоящее время база данных Регистра включает медицинскую и дозиметрическую информацию на 230 тыс. человек, в том числе на 144 тыс. ликвидаторов и 73 тыс. жителей наиболее загрязненных радионуклидами территорий России.

К группам повышенного радиационного риска в Регистре относятся ликвидаторы, принимавшие участие в восстановительных работах в зоне радиационного воздействия в 1986-1987 гг, а также дети, получившие значительные дозы облучения щитовидной железы.

Проведенный нами анализ динамики заболеваемости указанных выше групп показал, что в течение 7 лет после аварии наблюдается рост показателей как общей заболеваемости, так и по отдельным нозологическим формам. Вместе с тем, радиационно-эпидемиологические исследования, проведенные нами, не позволяют пока связывать рост показателей заболеваемости с дозой. Важное значение приобретает психосоматический фактор в оценке медицинских последствий Чернобыльской аварии.

セッション5
国際核不拡散のあり方—新たな情勢に対応して

<基調講演>
「国際核不拡散のあり方」
(社)日本原子力産業会議常任顧問
元軍縮会議日本政府代表部特命全権大使
今　井　隆　吉

<パネル討論>
パキスタン原子力委員会委員長
I. アッマド

国際原子力機関（IAEA）事務局長
H. ブリックス

フランス原子力庁（CEA）国際局長
H. ドラフォルテル

同　前
今　井　隆　吉

国際核拡散防止プログラム（PPNN）議長
B. サンダース

ほ　か

SUMMARY OF PRESENTATION OF DR. ISHFAQ AHMAD, CHAIRMAN, PAEC, TO MEETING ON "WAYS OF INTERNATIONAL NUCLEAR NON-PROLIFERATION - MEETING THE NEW SITUATION" IN TOKYO.

The presentation starts with a brief discussion of recent developments on the global nuclear scene. It dwells upon the original objectives for which the Non-Proliferation Treaty was enforced and critically evaluates the extent to which the Treaty has been successful in achieving those objectives.

The presentation emphasizes the counter productive nature of such measures as international embargoes imposed by Advanced countries on transfer of nuclear technology to developing countries for achieving non-proliferation. It then comments upon the feasibility of some of the proposals recently put forward for non-proliferation.

The presentation enumerates Pakistan's proposals for creating an equitable and non-discriminatory non-proliferation regime in south Asia, and ends with reiteration of Pakistan's commitment to global as well as regional non-proliferation.

THE 26TH JAIF ANNUAL CONFERENCE

Summary of Remarks by Ben Sanders
Session 5 - Panel on International Nuclear Non-Proliferation

Debates about the merits of the Non-Proliferation Treaty tend to raise strong emotions, reflecting the importance of the subject. The NPT is a treaty of immense international significance. With almost 160 parties it is the most important measure of arms control.

Judgments of the ways in which the Treaty meets the challeneges it was created to deal with vary greatly. But no matter how well or how badly one feels it copes with the issues it was created to help solve, those issues themselves are the most important subjects of international security that face todays world.

Now that the nuclear rivalry between the Superpowers is effectively over and START-1 and -2 have codified the end of their arms race, the fear of an imminent nuclear conflict between the two giants has virtually disappeared. The Chemical Weapons Convention has given the world the means of ridding itself of one particularly abhorrent means of warfare. Thus the world should have become a much more secure place than it was a few years ago.

On the other hand, partly because of the shift in international power structures, and partly as a result of growing regional tensions and the growing inability of the major powers to deal with them through the patron/client relationships that were a feature of the Cold War era, nuclear proliferation is taking over as the number one arms control problem in today's international arena.

The greater the problem, the more passionately its various aspects are debated, and the more carefully one scrutinizes and criticizes the application of any measure used to solve the problem. As to the NPT, right from its start, the way in which it approaches the problems has been condemned by some, criticized by many and recognized by everyone as less than perfect. Even the strongest supporters of the Treaty admit that it has imperfections, inherent in the situation it was created to deal with, and unavoidable under the circumstances of its creation.

Some see the shortcomings as basic and have refused to join. The great majority of nations have recognized and accepted them as the unavoidable price to pay for the advantages the Treaty offered, hoping that those advantages would come to outweigh the drawbacks. In the course of its life, the inequality inherent in a Treaty that imposed on the majority of the parties an obligation which a few did not share was to have been offset in the fairness of its implementation.

A central question for 1995 is one that was asked at each NPT review conference so far: whether indeed the implementation has been fair. Have those who retained their privileges under the Treaty made a significant effort to even out the inequalities, and does the result of those attempts justify the continued existence of the Treaty?

A second basic question arises from recent events in Iraq, in North Korea, and perhaps other countries which we suspect but cannot openly accuse of breaking their Treaty obligations: how effective is the Treaty in deterring the spread of nuclear capabilities?

If the answer to these basic questions is positive, the consequence is clearly a long-term extension of the Treaty. If it is not clearly so, we should ask a second question : is the Treaty worth conserving and extending? To answer this question, it is necessary to weigh the advantages and speculate on the what-if-not element hidden in such speculations as:

* Could the Cold War have ended in the way it did without the NPT?

* Would the Intermediate Nuclear Missile Force Reduction Treaty (INF) have been possible without the stabilizing influence of the NPT?

* Would the world reaction to Iraq's nuclear adventurism have been as strong without the embodiment in the NPT of the rule that making nuclear weapons is an act unacceptable to the world community?

* Would the opponents of a nuclearised Korean Peninsula have gathered so much support, without the general acceptance of the norm of non-proliferation, as reflected by the Treaty?

* Is it not safer for the average nation to abstain from manufacturing nuclear weapons and to demonstrate its nuclear innocence through the transparency of international verification?

* Would South Africa have submitted its nuclear activities and material to safeguards had there been no NPT?

In short, the question is, what has the Treaty achieved, at what cost?

Then there is a third question: could one create another treaty that could serve international stability and security as well as, or more effectively than, the NPT has done so far, and one which ensures true equality among nations? Is there any assurance that the world community could agree on a universal instrument for the abolition of nuclear weapons, that meets the security considerations of nuclear haves and have-nots? Is it possible to create an instrument that reconciles the policy of industrial nations not to pass on technologies or equipment that might be used to make nuclear weapons, with developing nations seeking to obtain all elements of the nuclear fuel-cycle? Is it likely that one can devise a treaty that attracts those who use nuclear means of ensuring security in regions of tension and also those who think nuclear abstinence will protect those regions? Can one envisage a catch-all Treaty that does everything and attracts everyone - each of the present 160 NPT-parties **plus** the hold-outs: India, Israel, Pakistan? Lastly: if one could devise such an instrument, which would have to reflect the highest common denominator of all these divergent interests and different nations, how effective would it be?

Finally, if the answer to the first questions is not a wholehearted affirmation; if the answers to the various parts of the second question lead one to give the NPT the benefit of the doubt, but also to feel that a more equitable situation is preferable; and if no viable universal alternative is in clear sight - then comes the main question: should the Treaty be extended, and for how long? Should and could that extension be tied to means of ensuring future implementation of the Treaty? If so, how?

That is the stuff of this conference and the basis for its decisions. I believe that the answer is clearly that a lengthy extension is essential in the interest of world peace and security.