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UC-28

REPORT OF THE WORKSHOP ON TRANSFERRING X-RAY LITHOGRAPHY SYNCHROTRON (XLS) TECHNOLOGY TO INDUSTRY

HELD AT
BROOKHAVEN NATIONAL LABORATORY
JULY 8, 1987

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OFFICE OF RESEARCH AND TECHNOLOGY APPLICATIONS
and the NATIONAL SYNCHROTRON LIGHT SOURCE

BROOKHAVEN NATIONAL LABORATORY
UPTON, LONG ISLAND, NEW YORK 11973

UNDER CONTRACT NUMBER DE-AC02-76CH00016 WITH THE
UNITED STATES DEPARTMENT OF ENERGY

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Executive Summary

A workshop was held at Brookhaven on Wednesday, July 8, 1987, to explore mechanisms to transfer x-ray lithography synchrotron (XLS) technology. Identification of an effective technology transfer mechanism is one of several goals of the six month preconstruction study underway at BNL.

The meeting was attended by 35 persons including 17 representatives from nine companies. The product of the workshop was a consensus on an approach for transferring the technology by means of an industrial support contract. The elements of this arrangement are:

1. Brookhaven will supply preliminary specifications to preselected qualified companies to develop a preliminary design for a prototype XLS. Some government support will be requested for this preliminary design phase.

2. By the end of calendar year 1987, the selected companies will prepare a proposal for a competition for implementation of the project. The winner will perform a Title II detailed design and also carry out Title III construction of the prototype machine. BNL staff will be available for consultation and mutually agreed upon work on the project. The winning contractor will be responsible for implementation of the contract. Brookhaven will have approval authority of design drawings and specifications and cost estimates.

3. The final stage will be commissioning and operation. In this stage, the Laboratory as customer will bring the machine on line and up to a satisfactory operating level. Since this is the area in which the Laboratory's experience is most important, this activity could be opened to those who had prepared proposals but had not been selected in the earlier competition. Through this means the option is left open to have more than one potential XLS supplier at the end of the program.

The outcome of this workshop will be incorporated in the preconstruction study report as one possible approach for funding allocation for the continuation of this effort. The ability of the industrial participants to reach a consensus position enhances the likelihood of a speedy and successful transfer of this important technology.

Report of the Workshop on Transferring X-ray Synchrotron Lithography (XLS) Technology to Industry

Brookhaven National Laboratory

July 8, 1987

1.0 Background

In March, 1986, Brookhaven invited American companies in the semiconductor product and equipment industries to a workshop. The workshop served to inform the industry that the technology for an x-ray lithography synchrotron (XLS) was resident at BNL and other DOE accelerator Laboratories and was available for transfer to American industry. Since European and Japanese efforts were already underway to develop this long-lead time technology, U.S. industry would have to respond quickly while a window of opportunity still existed.

The discussions at the workshop clearly exceeded the original scope of the meeting which was to provide a platform for the semiconductor industry to collectively address and speak on the issues and needs associated with sub 0.25 micron chip production. During the meeting the urgency was made clear as well as the interests of industry to engage in cooperative development of x-ray lithography using the existing technology base for design of XLS sources.

The workshop established that the window of opportunity for U.S. industry to develop 0.25 micron x-ray lithography was still open. Parameters were established for x-ray lithography and for a compact x-ray lithography source.

A steering committee was established at the March workshop and subsequently they recommended that Brookhaven prepare straw man designs to be the subject of a second workshop. Two designs were prepared, one for a conventional ring, the second for a cryogenic compact ring. These were presented to a workshop in August, 1986.

The August meeting concluded that a wide technology base will be necessary to attain commercially successful 0.25 micron devices and that an industry/National Laboratory partnership was needed to support the development of synchrotron sources.

The recommendations of this workshop were:

- as soon as possible construct an x-ray lithography facility using a conventional synchrotron.
- develop a superconducting source and low energy injection.

- distribute second generation machines to IC manufacturing centers.
- 5 commercialize technology.

The steering committee then proposed that preliminary cost and schedule estimates be prepared. A third workshop was convened at Brookhaven in November, 1986, to accomplish this. The product was a six year plan for a full 0.25 micron lithography capability that would cost about $400 million. Of the $400 million, $40 million was the estimated cost of the XLS prototype. The result of the three workshop efforts is that an industrial consensus has been reached in defining the parameters of the system and the time scale and the costs for system development.

In February, 1987, the National Research Council conducted a workshop where representatives of the U.S. semiconductor industry and Department of Energy National Laboratories met to explore areas of opportunity and mechanisms for collaboration of DOE National Laboratories and the semiconductor industry. The Brookhaven/industry proposal developed in the November workshop was presented. Shortly thereafter, Brookhaven was provided with FY 87 funding from the Defense Department to carry out a preconstruction study. Part of that study is to identify a formula whereby industry and the Laboratory can interact during the construction of an XLS prototype so as to transfer the technology and create at least one American industrial entity that will produce synchrotrons for a commercial market.

2.0 Objectives

2.1 Objective of XLS effort

The objective of the XLS effort is that within a 30 to 36 month period several U.S. companies will be able to offer the semiconductor industry proven, reliable and effective sources for x-ray lithography. These sources must be competitive with those that will become available from foreign suppliers both in performance and in cost.

The earlier workshops concluded that to fulfill this objective in the most rapid and effective manner required that a prototype system be built. Moreover, it required exposure to the design, construction and particularly the commissioning of the prototype XLS by industrial partners.

2.2 Objective of Preconstruction Study

The objective of the preconstruction study is to perform preliminary design and implementation studies so that construction and commissioning of an XLS prototype will occur at the earliest possible date once the decision is made to fund and build it.

Recommendations for approaches to be used to assure that the essential elements of synchrotron technology are transferred from the Laboratory to industry is a major requirement of the preconstruction study.

2.3 Objective of the Technology Transfer Workshop

The objective of the workshop was to provide recommendations for industry/BNL/government interactions during the prototype XLS project that would be acceptable to industry and effectively transfer technology.

This workshop is aimed at providing recommendations that will fulfill the requirement for the preconstruction study to identify effective approaches to technology transfer.

3.0 Presentations

A copy of the Agenda is attached as Appendix 1. This section presents a short summary of the presentations that were presented prior to discussing approaches for technology transfer.

3.1 Introduction

Dr. S. Baron introduced the workshop by stating the goal of arriving at a recommendation for Laboratory/industry interaction during construction of the prototype to transfer synchrotron technology to industry. Dr. M. Blume, Deputy Director of the Laboratory and Mr. J. Bellows, Manager of the DOE Brookhaven Area Office greeted the attenders. Both emphasized the importance of the project and the eagerness of the Laboratory and the Department to transfer the technology to industry. Dr. Blume pointed out that Brookhaven had been funded to perform a preconstruction study, part of which is to identify approaches for achieving the transfer of technology. He also pointed out the current interest in Congress and the Administration to move this technology into industry.

Dr. M. Knotek, Head of the National Synchrotron Light Source (NSLS), described the NSLS and the interactions that have been developed with industry to date. He pointed out that the formula developed at this workshop will be a natural succession to the developing interaction between industry and the Laboratory. This represents a new dimension in that the NSLS is moving from supplying photons from the ring to supplying the technology for the ring itself. In three years we should not only have a prototype machine built and in operation, but the knowhow transferred to your organizations so you can go ahead and commercialize this technology.

3.2 Preconstruction Study Description, Goals and Objectives

Mr. J. Godel, who is heading up the preconstruction planning study, stated why the results of this workshop are so important to the study. A copy of the viewgraphs used in his presentation are attached as Appendix B. The objective of the XLS program is that in 30 to 36 months several U.S. companies will be able to manufacture and supply the semiconductor industry with proven, reliable and effective sources for X-ray lithography. To attain this goal BNL must learn how to integrate our work effectively with industry participants. We must also assure the funding agency that industry will retain their interest in producing x-ray sources.

The problems that are faced by industry are:

- the market is long-range and there is risk that it may not materialize or that we may not get there first.
- the number and skills of the people to be committed to the project team.
- should each interested company supply the full number of required staff in place, or should key positions be filled from different companies with the understanding that all data will be available to all participating firms?
- should the industrial participants be compensated in whole or in part by the government?
- patent agreements and intellectual property rights.

Mr. Godel pointed out that technology transfer was a two way process. BNL has specific skills. experience and a support structure that has evolved in designing, building, commissioning and operating synchrotron light sources. Industry has specific skills in managing high technology projects and in optimizing manufacturability, cost effectiveness and systems and

human engineering that is necessary for reliability and economy in commercial sources. Mr. Godel concluded by presenting a schematic that illustrated the major subsystems associated with an x-ray synchrotron and where there would be a technical association between the Laboratory and industry.

3.3 XLS Technology

Dr. Richard Heese, who is head of the machine design activity in the preconstruction study, spoke about elements of XLS technology that would have to be shared between the Laboratory and industry. In particular, he pointed out that the experience of the Laboratory staff with the difficulties associated with making the machine work once the hardware is in place represents a Laboratory resource that is of great importance for this effort. In fact, it is this capability that makes us competitive with foreign competition even though they have had x-ray lithography efforts in place for several years.

3.4 Lessons Learned in Transferring Technology from Government to Industry

Dr. Baron summarized some of the technology transfer experiences of government developed nuclear technology to industry. Although these examples may not be analogous to the XLS experience, the lessons learned in transferring nuclear technology may be useful. Reactor transfer was grouped into three stages. The early stage was marked by many mistakes due to simplistic assumptions and each participant going in a different direction. The lesson to be learned was there was no effort to bring the limited talent together to work on a few productive ideas.

The second stage was marked by companies jumping into commercialization with fixed-price plants priced to be competitive with coal. The lesson to be learned was that there was inadequate information feedback and the limited amount of expertise was badly diluted.

The third stage was to move toward a standard design to decrease licensing and manufacturing problems. The French have taken this idea to a successful conclusion in part by keeping the teams together from plant to plant.

The breeder program also contains some lessons. Initially, the team that was put together to build the Fermi facility had never worked together and were poorly integrated. The government's FFTF effort went to the other extreme and imposed so much regulation that it bogged down. The Clinch River demonstration brought together individual industrial and engineering organizations to work together. Then they were asked to collectively agree to a design that all would feel comfortable bidding against. Although Clinch River was cancelled, that was for other reasons and the model appeared very promising.

3.5 Technology Transfer Scenarios

Dr. Marcuse introduced some straw man models of technology transfer scenarios. The viewgraphs of this presentation will be found in Appendix C. The models presented spanned the spectrum of individual company participation, involvement and support. The research associate model permitted maximum participation but with minimal structure and considerable government support. At the other extreme, early selection of a single company, or a few companies to be winnowed down to one, limits the openness of the participation, but permits a much more organized approach and less support cost to the government. Other models lay intermediate between these two extremes.

4.0 Discussion

At the completion of the prepared presentations, Dr. Baron led an open discussion aimed at arriving at general recommendations for an effective formula for technology transfer.

The following issues were introduced and discussed:

- At the conclusion of the prototype effort one or more entities must exist that are ready to bring the product to market and stand behind it. This requires a critical mass of people and a partnership role in the activity.
- Since the size of the market is small and it may not exist if the foreign producers get there first, government support is needed to overcome both timing and multiple supplier risks. Even if U.S. industry is the first to produce a commercial XLS, the market will not materialize until the process technology is fully developed and government support is necessary because of the long lead time.

- Alternatives are a single system integrator vs breaking up the effort into separate pieces. The preference was for selection of a system integrator or prime contractor who would deliver a machine built to specifications prepared by BNL. There is a conflict between fast tracking that leads to a single supplier and an approach that will get a number of industrial entities ready for XLS production.
- Conflict between BNL's desire to solely design and build the machine and the alternative of helping industry build it and transfer technology. Industry must play a significant role in constructing the machine and then work closely with BNL during the commissioning.
- Industry is comfortable with traditional approach where performance specifications are issued, teams are formed, proposals are submitted, and one or more of the proposals are selected. In this case they would work with the Laboratory during execution with the Laboratory maintaining approval of design and cost decisions.

At this point the workshop broke for lunch. When it reconvened Mr. Godel attempted to summarize the morning discussions. He presented a five stage approach. The subsequent discussion dealt with leadership roles and funding. The workshop adjourned within an hour. The following presents a consensus view which is a modified version of Mr. Godel's five phases.

Phase A - Preliminary Design and Familiarization - BNL would prepare a scope of work. Industry would submit indications of interest and qualification. Qualified bidders would be selected. All qualified entities would review the scope of work and become familiar with the performance specifications and preliminary design. The Laboratory and its staff would be available to them to gain familiarity with the conceptual design and to learn about the NSLS experience. This would be a Title I design phase and the government would provide some of the funding.

Phase B - Proposal Preparation - During this phase industrial entities would prepare proposals to contract and deliver a ring at specifications with their cost and schedule estimates. It would end with selection of a winning proposal. The proposals would be funded by the individual companies.

Phase C - Detailed Design -This phase would consist of the winning bidder preparing a Title II detailed design. BNL would act as owner with design and cost approval responsibility during the design period. If conflict of interest problems can be avoided, BNL staff would be available to the system integrator for consultation and actual work. Individual subsystems may be contracted for with other entities than the system integrator.

This phase would be funded by the government.

Phase D - Construction - This phase would consist of Title III, Construction of the ring. The systems integrator would act an architect engineer and BNL would act as owner. This phase would be funded by the government.

Phase E - Commissioning and Operations - During this phase, BNL has the primary responsibility. The BNL staff would train the system integrator staff and support will be supplied by the system integrator. It may be possible to permit entrants who lost the original competition but continued to support their own efforts during the construction and design phases to participate in commissioning and operations. Funding would be supplied by government.

5.0 Recommendations

The recommendations of the workshop follow:

1. Brookhaven will supply preliminary specifications and design information to preselected qualified companies. Some government support will be requested for these companies for this preliminary design effort.
2. By the end of calendar year 1987, the selected companies will prepare a proposal for a competition for implementation of the project. The winner will perform a Title II detailed design and also carry out Title III construction of the prototype machine. BNL staff will be available for consultation and mutually agreed upon work on the project. The customer for the synchrotron will be the Laboratory and the winning contractor will be responsible for implementation of the contract. Brookhaven will have approval authority of design drawings and specification and cost estimates.
3. The final stage will be commissioning and operation. In this stage, the Laboratory as customer will bring the machine on line and up to a satisfactory operating level. Since this is the area in which the Laboratory's experience is most important, this activity could be opened to those who had prepared proposals but had not been selected in the earlier competition. Through this means the option is left open to have more than one potential XLS supplier at the end of the program.

6.0 Conclusions

BNL will write a procurement plan so as to be ready to implement the recommendations at the earliest possible date. The plan must be fast tracked because selection will be made by early calendar year 1988.

The elements of the plan are:

1. Industry provides indication of interest and capability to undertake detailed design and construction of XLS prototype.
2. BNL provides documents, data and design information to qualified industrial entities. BNL also provides access for preproposal familiarization.
3. BNL issues RFP for Title II (Detailed Design) and Title III (Construction) of XLS prototype.
4. Industry prepares responses to RFP.
5. Selection of winner.

APPENDIX A

AGENDA

XLS WORKSHOP

BROOKHAVEN NATIONAL LABORATORY

Berkner Hall, Room B
July 8, 1987

8:30 a.m. Welcome - M. Blume - Deputy Director, BNL

- J. Bellows - Manager, Brookhaven Area Office of the Department of Energy

Overview - M. Knotek

9:00 Preconstruction Study Description, Goals and Objectives - J. Godel

9:20 XLS Technology - R. Heese

9:40 Coffee break

9:50 Lessons Learned in Transferring Nuclear Technology - S. Baron

10:10 Scenarios - W. Marcuse

10:30 Discussion led by S. Baron

12:30 Lunch, Berkner Hall, Room A

1:00 Discussions (cont'd)

3:00 General Recommendations - S. Baron

4:00 - 5:00 Summaries and conclusions

APPENDIX B

Illustrations from Presentation By J. Godel on the Preconstruction Study: Description, Goals and Objectives

PRECONSTRUCTION STUDY

- SIX-MONTH STUDY SPONSORED BY DOD TO CARRY FORWARD RECOMMENDATIONS OF THIRD WORKSHOP IN DEVELOPING X-RAY LITHOGRAPHY SOURCE CAPABILITIES

- PROGRAM WILL RESULT IN A WARM MAGNET X-RAY SOURCE AT BROOKHAVEN IN ABOUT 30 MONTHS AND R&D FOR A CRYOGENIC MAGNET SOURCE

- TECHNOLOGY TRANSFER IS AN ESSENTIAL ELEMENT IN PROGRAM

TECHNOLOGY TRANSFER

OBJECTIVE:

BY 1990, ONE OR MORE U.S. COMPANIES WILL BE ABLE TO OFFER SEMICONDUCTOR INDUSTRY A TURNKEY X-RAY LITHOGRAPHY SOURCE THAT IS PROVEN AND RELIABLE.

TECHNOLOGY TRANSFER: A TWO-WAY PROCESS

- BNL HAS SPECIFIC SKILLS, EXPERIENCE, AND SUPPORT STRUCTURE TO DESIGN, BUILD, COMMISSION, AND OPERATE A SMALL SYNCHROTRON LIGHT SOURCE FOR X-RAY LITHOGRAPHY

- INDUSTRY HAS SPECIFIC SKILLS TO MANAGE HIGH-TECH PROJECTS AND OPTIMIZE MANUFACTURABILITY, COST EFFECTIVENESS AND SYSTEMS, AND HUMAN ENGINEERING WHICH ARE NECESSARY FOR RELIABILITY AND ECONOMY IN SECOND GENERATION SOURCES

PROBLEMS TO BE FACED BY INDUSTRY

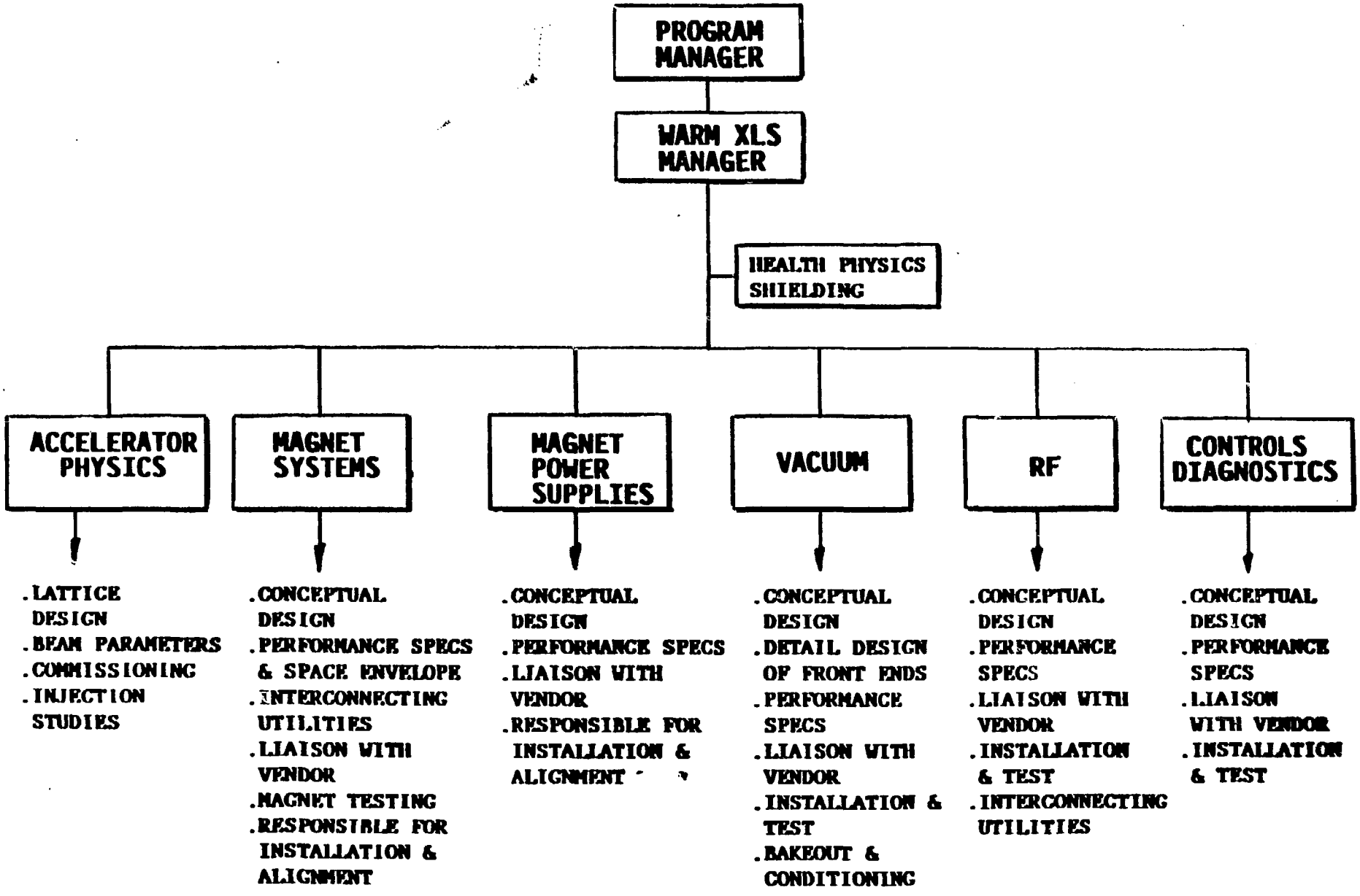
- HIGH RISK, LONG RANGE MARKET

- HOW MANY PEOPLE SHOULD EACH FIRM COMMIT TO THE PROJECT TEAM?

- SHOULD EACH INTERESTED COMPANY HAVE A FULL NUMBER OF REQUIRED STAFF IN PLACE, OR SHOULD KEY POSITIONS BE FILLED FROM DIFFERENT COMPANIES, WITH UNDERSTANDING THAT ALL DATA WILL BE AVAILABLE TO PARTICIPATING FIRMS?

- HOW SHALL THESE PARTICIPANTS BE COMPENSATED?
  - GOVERNMENT FUNDED?
  - PARTIAL SPONSORSHIP BY INDUSTRY?

- PATENT AGREEMENTS AND RIGHTS


PROGRAM MANAGER
WARM XLS MANAGER
HEALTH PHYSICS SHIELDING
ACCELERATOR PHYSICS
MAGNET SYSTEMS
MAGNET POWER SUPPLIES
VACUUM
RF
CONTROLS DIAGNOSTICS
.LATTICE DESIGN
.BEAM PARAMETERS
.COMMISSIONING
.INJECTION STUDIES
.CONCEPTUAL DESIGN
.PERFORMANCE SPECS & SPACE ENVELOPE
.INTERCONNECTING UTILITIES
.LIAISON WITH VENDOR
.MAGNET TESTING
.RESPONSIBLE FOR INSTALLATION & ALIGNMENT
.CONCEPTUAL DESIGN
.PERFORMANCE SPECS
.LIAISON WITH VENDOR
.RESPONSIBLE FOR INSTALLATION & ALIGNMENT
.CONCEPTUAL DESIGN
.DETAIL DESIGN OF FRONT ENDS
.PERFORMANCE SPECS
.LIAISON WITH VENDOR
.INSTALLATION & TEST
.BAKEOUT & CONDITIONING
.CONCEPTUAL DESIGN
.PERFORMANCE SPECS
.LIAISON WITH VENDOR
.INSTALLATION & TEST
.INTERCONNECTING UTILITIES
.CONCEPTUAL DESIGN
.PERFORMANCE SPECS
.LIAISON WITH VENDOR
.INSTALLATION & TEST

APPENDIX C

Illustrations from Presentation by

W. Marcuse on Technology Transfer Scenarios

OUTLINE

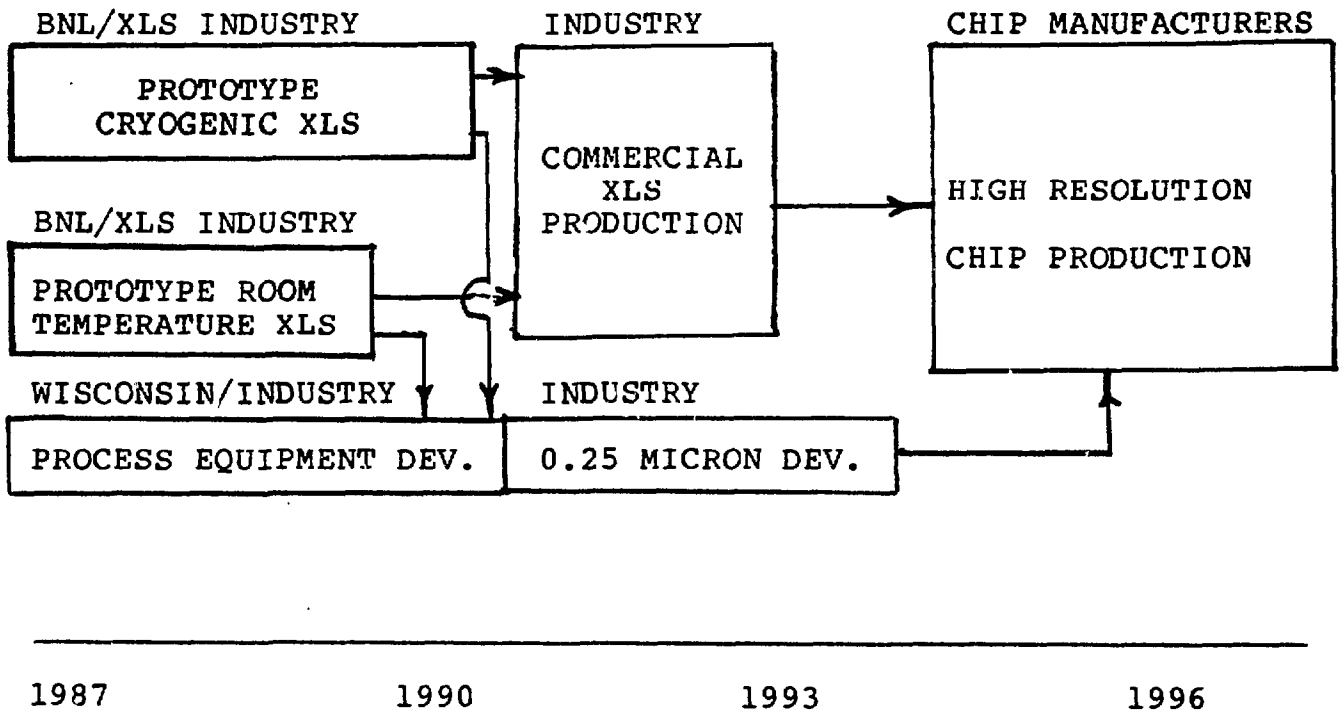
1) STATEMENT OF WORKSHOP GOALS
2) TOTAL PROGRAM IMPLEMENTATION
3) BNL/INDUSTRY INTERACTION
4) DIMENSIONS
5) TECHNOLOGY TRANSFER SPACE
6) INTRODUCTION TO MODELS
7) MODEL FLOW CHARTS
8) CHARGE TO WORKSHOP GROUP

GOALS OF WORKSHOP

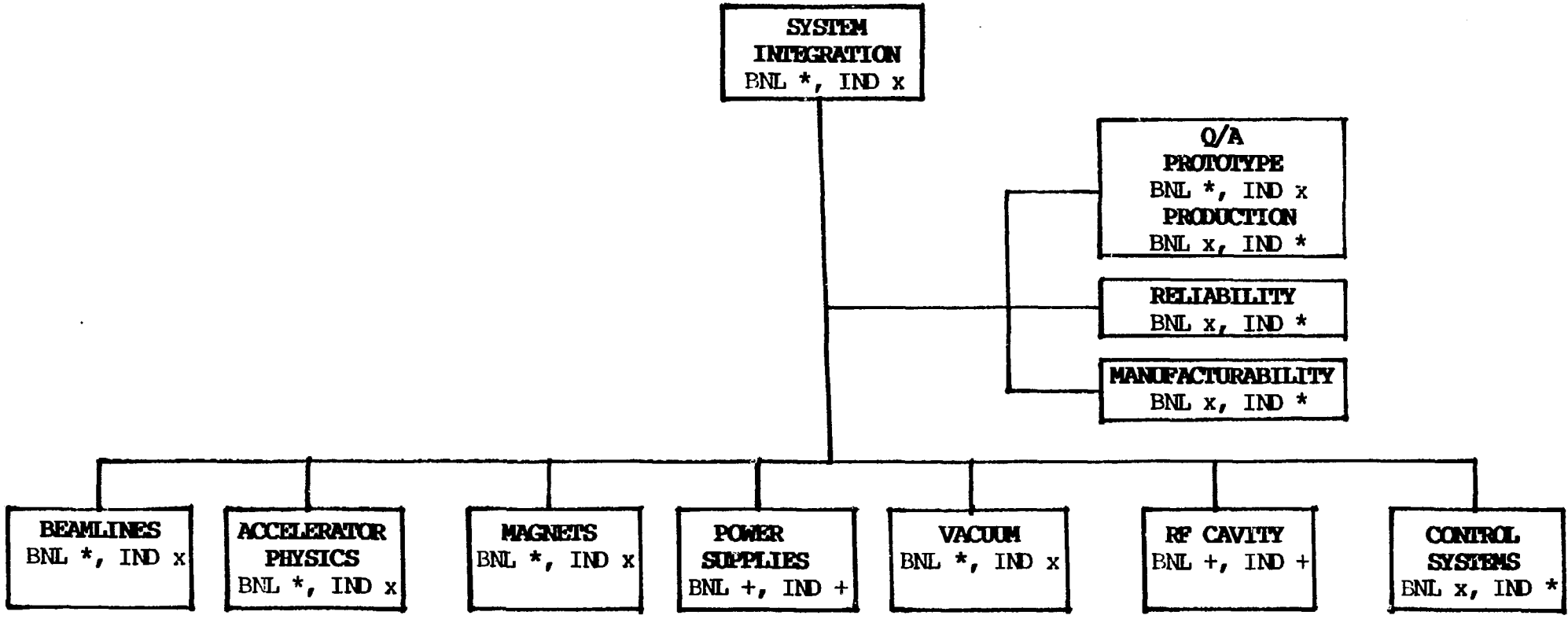
RECOMMENDATIONS FOR INDUSTRY/BNL INTERACTION DURING PROTOTYPE XLS DESIGN, CONSTRUCTION AND COMMISSIONING

TOTAL PROGRAM IMPLEMENTATION

XLS COMMERCIALIZATION



BNL/INDUSTRY INTERACTION
XLS ROOM TEMPERATURE PROTOTYPE



* Lead
x Participant
\+ Collaborator

DIMENSIONS

PARTICIPATION

OBSERVER–HANDS ON–DESIGN–MANAGEMENT

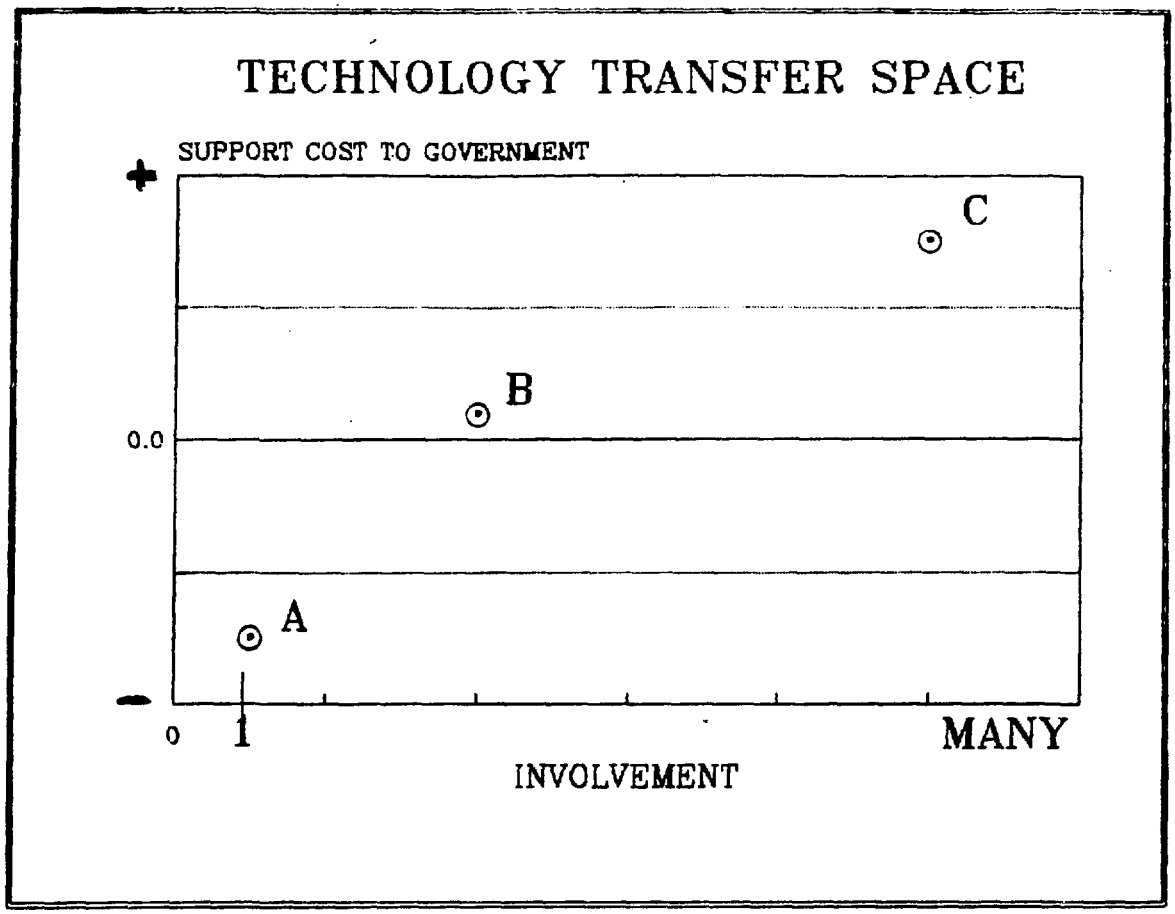
eg – OBSERVER, ACCELERATOR PHYSICS
– HANDS ON, VACUUM
– DESIGN, MAGNETS
– MANAGEMENT, CONTROL SYSTEMS

INVOLVEMENT

EACH COMPANY AT ALL LEVELS
EACH COMPANY AT SELECTED LEVELS
SELECTION OF ONE OR A FEW COMPANIES

SUPPORT

COMPANIES BID FOR SOLE PARTICIPATION
COMPETITION FOR SELECTED PARTICIPATION
GOV'T SUPPORTS OPEN PARTICIPATION



A – SINGLE PRESELECTED FIRM

B – SEVERAL FIRMS SELECTED

C – UNLIMITED PARTICIPATION

INTRODUCTION TO MODELS

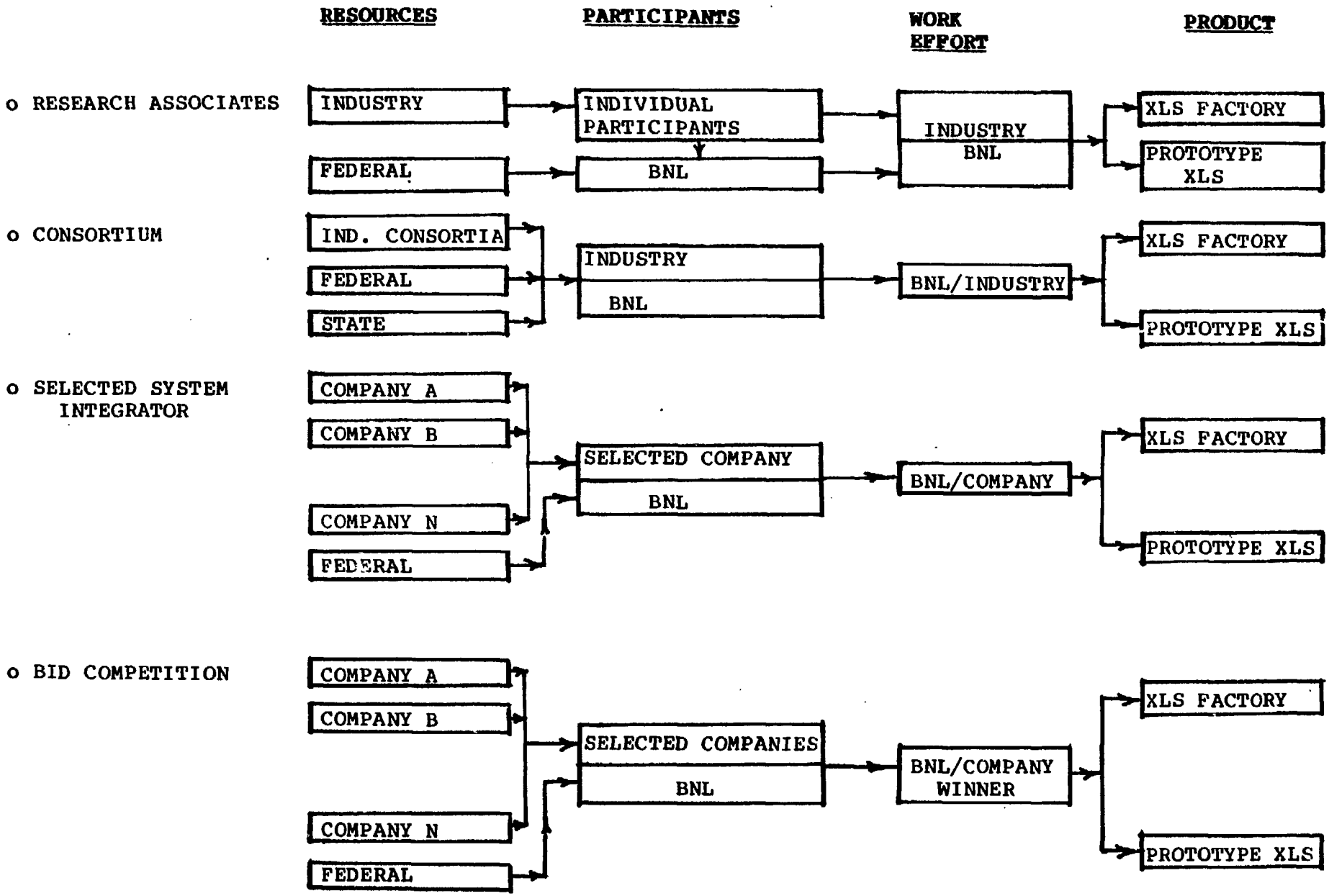
RESEARCH ASSOCIATES
- UNSTRUCTURED
- OPEN TECHNOLOGY CHOICES FOR INDUSTRY
- MAXIMUM INDUSTRIAL INVOLVEMENT

CONSORTIUM
- DIFFICULT TO CREATE
- COMMITMENT TO XLS PRODUCTION FACILITY
- LARGE INDUSTRY ROLE
- LIMITS RESOURCE REQUIREMENTS

SELECTED SYSTEM INTEGRATOR
- LIMITS PARTICIPATION BY LOSERS
- RISK IS FUNCTION OF GOVERNMENT SUPPORT
- DIFFICULT TO SELECT WINNER

BID COMPETITION
- MAXIMUM INDUSTRY INVOLVEMENT EARLY-ON
- MAY LEAD TO CONSORTIUM
- FINAL SELECTION IS DIFFICULT

MODELS


RESOURCES
PARTICIPANTS
WORK EFFORT
PRODUCT
o RESEARCH ASSOCIATES
INDUSTRY
FEDERAL
INDIVIDUAL PARTICIPANTS
BNL
INDUSTRY
BNL
XLS FACTORY
PROTOTYPE XLS
o CONSORTIUM
IND. CONSORTIA
FEDERAL
STATE
INDUSTRY
BNL
BNL/INDUSTRY
XLS FACTORY
PROTOTYPE XLS
o SELECTED SYSTEM INTEGRATOR
COMPANY A
COMPANY B
COMPANY N
FEDERAL
SELECTED COMPANY
BNL
BNL/COMPANY
XLS FACTORY
PROTOTYPE XLS
o BID COMPETITION
COMPANY A
COMPANY B
COMPANY N
FEDERAL
SELECTED COMPANIES
BNL
BNL/COMPANY WINNER
XLS FACTORY
PROTOTYPE XLS

CHARGE TO WORKSHOP GROUP

MAKE RECOMMENDATIONS FOR INDUSTRY/ BNL/GOVERNMENT INTERACTIONS DURING PROTOTYPE XLS PROJECT

APPENDIX D

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July 8, 1987

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