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Advanced Technology Needs for a Global Change Science Program

Perspective of the Langley Research Center

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Foreword

Many scientists, engineers, and concerned citizens, both within the United States and abroad, are increasing our awareness of the real and potential damage that mankind is inflicting on Earth. Governments are responding with plans and resources, first, to understand the mechanisms at play and, then, to develop policies to protect the delicate balance of forces that shape our environment. The National Aeronautics and Space Administration (NASA) is one of the United States agencies involved in this effort, and one role NASA must perform well is the identification and development of advanced sensing methods, components, and operational spacecraft to support the scientific investigators. Therefore, NASA's Office of Aeronautics and Space Technology (OAST),[1] working with the field centers, initiated a concentrated effort to identify and prioritize the elements that should make up a technology program focused on global change science requirements.

Langley Research Center (LaRC) senior management selected a team of representatives from its science and technology development areas to assist in identifying and describing those LaRC technologies that would be beneficial to a global change science program. This team, known as the Global Change Technology Initiative (GCTI) Task Force, was responsible for generating the technology material listed in section 3. The Task Force members (listed below) and other LaRC personnel participated in a series of three workshops sponsored by NASA Headquarters (HQ) for synthesizing inputs from all the NASA centers. Having completed this initial effort in support of NASA OAST, the Task Force will continue, as appropriate, to provide HQ and LaRC senior management with information about those technologies listed in this report or others that are newly identified as being critical to the GCTI.

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[1] Reorganized in 1990 to be OAET (Office of Aeronautics and Exploration Technologies).

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1. Introduction

Since the launch of the first Television and Infrared Observation Satellite (TIROS) in April 1960, the United States has made tremendous strides in the application of satellite remote sensing to the study of Earth's land, oceans, and atmosphere. The growth in remote sensing technology and operations has benefited not only the science community, but also the business sector and society as a whole by providing both an increased understanding of the Earth system and an associated improvement in predictive capability (ref. 1). The two principal federal agencies involved in the development and use of remote sensing are the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA), though many other agencies such as the National Science Foundation, Department of the Interior, Department of Agriculture, Department of Defense, Department of Transportation, and Environmental Protection Agency have developed diverse uses for the data that are produced.

Although we now view predictions of weather and severe storms as commonplace, this was not possible before observational technologies, analysis techniques, and operational spacecraft were available. For the larger task of developing even simple predictive models of the total Earth system, many additional measurement variables must be collected at greatly increased temporal and spatial frequencies so that the complex interactions among the hydrological cycle, the biogeochemical cycle, and the climate can be understood. A growing international concern regarding trends such as ozone depletion, global warming, and acid rain is generating an intense renewed emphasis on Earth science and on the associated support technologies that are needed to enable a comprehensive global change program such as Mission to Planet Earth (ref. 2). Many NASA responsibilities will bear upon the success of a global change science program; foremost among these activities will be research and development of advanced space technologies and systems. Adequate measurement techniques and operational systems have not been developed to collect the vast amounts of data needed to understand the complex interactions among the surface, oceanic, atmospheric, and biological elements of the planet. Major advances in observation techniques and sensors, data and information handling, and spacecraft and operations technologies must be achieved before the multidisciplinary science measurements (discussed in section 2) can be made and analyzed over sufficiently long time periods.

To this end, NASA is defining a technology program intended specifically *to enable and enhance a global change science program.* This Global Change Technology Initiative (GCTI), proposed for a funding start in the 1991 fiscal year, will develop, to the extent that the budget allows, the top-priority technology candidates in three major areas: observation technologies, data and information technologies, and spacecraft and operations technologies. NASA Headquarters (HQ) has involved the field centers in an intensive study to identify and prioritize the technology candidates. This paper presents the elements of the Langley Research Center (LaRC) technology development work (discussed in section 3) that are believed to be very important to the global change science program. Not all these elements are likely to be funded by the GCTI. Technical evaluations by NASA HQ and budget issues will determine which of the LaRC elements will be selected along with elements proposed by other centers for inclusion in the eventual GCTI proposal. The final content of the GCTI program will be documented by NASA HQ.

This paper will present briefly the science requirements for a global change program. These global change science issues and related measurements must, of course, be addressed by some sensing strategy, and the candidate sensors proposed for each measurement will be summarized. Technologies that are now or will be proposed as part of the LaRC technology development program which enable or enhance these measurements will be described. Detailed descriptions will be given for each proposed technology, including the scope, objective, and approach for that candidate; a technology readiness timeline; a list of deliverables; and an estimate of funding required to meet the deliverable milestones. This report, documenting the products of the LaRC GCTI Task Force, will be provided to NASA HQ to support their efforts to develop a GCTI proposal for presentation to the NASA Administrator.

2. Global Change Science Requirements

Global-scale changes now occurring in the chemical composition of the atmosphere threaten serious alterations of the Earth's climate. Some of the more significant environmental issues recently identified include

The greenhouse effect and possible global warming: Such changes in the Earth's atmospheric composition may result from factors such as increased fossil fuel burning.

Ozone depletion: Dramatic seasonal ozone losses have been detected in both the Arctic and the Antarctic polar regions. There exists a strong potential link between man-made pollutants and these ozone losses.

Tropical deforestation: The destruction of the tropical rain forests is a significant contributor to the atmospheric carbon dioxide increases.

To understand these changes, identify their sources, and predict their consequences requires extensive global-scale observations and associated advanced new instrumentation and spacecraft. Numerous studies completed in recent years by U.S. and international agencies have listed the primary measurements that must be made if global change processes are to be understood, modeled, and predicted. One of the most comprehensive studies was conducted by the Earth System Sciences Committee of the NASA Advisory Council between 1983 and 1987. Its report, known as the Bretherton report (ref. 3), has provided an informative and often-quoted source of the issues and the possible courses of action to understand global change. The report has served as the basis for the global change science requirements described in this section, and the summary tables from the report have been augmented by additional measurement needs proposed by scientists interviewed at several NASA field centers.

Measurement Requirements

The NASA field centers including the Jet Propulsion Laboratory (JPL), the Goddard Space Flight Center (GSFC), and the Langley Research Center (LaRC) surveyed their Earth scientists to identify any measurements beyond those listed in the Bretherton report that were deemed important. The study at JPL was conducted by Bob Gershman, at GSFC by Scott Shipley of ST Systems Corp. (STX) (GSFC internal report entitled "Science Traceability for the Global Change Technology Initiative"), and at LaRC by Tom Swissler. The scientists surveyed at LaRC are primarily atmospheric scientists, and consequently their additions to table I relate primarily to trace gases that play a major role in global change through the climate and biogeochemical areas.

Table I is a list of the measurement requirements combined from these sources and an internal report produced by the Geostationary Platform Earth Sciences Steering Committee (GPESSC) at Marshall Space Flight Center. (Internal report entitled "Geostationary Science Steering Group Committee Report: Understanding Dynamic Earth System Processes—The Need for Geostationary Observations.") The table describes the measurement objective, the target of the observation, the temporal and spatial resolutions, the percentage accuracy required, clarification comments, the potential measurement methods, and the various sources that identified the measurement as being important. The LaRC, JPL, and GSFC items included are additions to the Bretherton list. The GPESSC items include all measurements mentioned in their report whether or not identified already by the Bretherton report. A total of 108 measurements are identified in this list, and they are divided into the following categories: solar irradiance; tropospheric constituents (trace gases, ozone, aerosols, clouds); stratospheric constituents (trace gases, ozone, aerosols); atmospheric response variables (temperature, pressure, wind, precipitation, radiation components); surface characteristics (soil moisture, vegetation index, biomass burning, volcanoes, albedo); ocean variables (temperature, sea ice extent, sea level, CO_2 content); and plate motions. No doubt others could be added by scientists in disciplines not well represented within this table. The fact that several instruments (and resolutions) may be proposed for many of these measurements indicates that different applications can be made of a single science measurement.

Measurement History

Table II presents the history and current status of these measurements. The first two columns of table II are repeated from table I, but additional information has been presented. As is shown in this table, of 108 observables listed, 86 are currently being measured (at some resolution). Of these, only 50 have been measured by space-based systems, implying that the remainder have unacceptable temporal or spatial coverage. In fact, most of these measurements require enhanced spatial and temporal resolution in order to achieve the global coverage needed to infer knowledge of climate and global change. Thus, the need for greatly increased operational systems is obvious. Whether these unaccomplished measurements should be taken from in situ, aircraft, or spacecraft platforms will be determined by the coverage and repeat frequency requirements. For example, global climatology studies require long-term, accurate measurements on a global scale, while regional process studies require short-term measurements with high temporal resolution.

For 22 of these measurements, no routine operational sensor exists. Twelve of these measurement requirements are considered to be equivalent to the Bretherton report category of essential priority (No. 3), nine are in the category of highly important (No. 2), and one is in the category of substantially important (No. 1).

The importance of these measurement requirements can be better understood by citing some of their roles in global change characterization:

Ozone depletion: requirements for global daily measurements of stratospheric ozone and related photochemically important stratospheric trace gases

Greenhouse warming: requirements for global daily measurements of atmospheric temperatures, radiation budget components, trace gases and particulates, ocean parameters, and wind fields

Air pollution: requirements for measurements of tropospheric gases, particulates, precipitation, and pH of rain and clouds

Land surface characteristics: requirements for measurements of soil moisture, precipitation, cloud cover, radiation budget components, land surface temperatures, vegetation coverage, surface roughness, and river runoff

Transient events: requirements for measurement information on volcanoes, earthquakes, and floods

The particular intent of a given measurement requirement will affect the sensor selection and the resolution desired. For example, techniques and resolutions needed to measure cloud-top altitudes may be different from those needed to estimate location and extent of cloud cover. Thus, the extensive array of measurements in table I indicates those sensors needed aboard orbiting spacecraft for conducting space-based remote sensing, and table II indicates the deficiencies in the sensor maturity or operational status. The technologies needed to enable those sensors, to handle the resultant data, and to support their operation in the space environment are the technologies of interest to GCTI.

3. Advanced Technology Needs

A series of three workshops was sponsored by NASA HQ to gather the total NASA input to the GCTI program. The format used to present each technology proposed at these workshops was a four-quadrant chart ("quad" chart) which summarized the highlights of the proposal. These charts (LaRC's proposals are presented in the appendices) provide a detailed description of each technology as follows: the upper left quadrant gives the scope, objective, and rationale for the proposed technology; the upper right quadrant discusses the proposed approach as well as a list of deliverable items; the bottom left quadrant presents the writer's estimate of the schedule for achieving the technology readiness levels (defined in table III), and the bottom right quadrant presents the writer's estimate for the funding and manpower required to accomplish each identified deliverable. The name of the quad chart writer is indicated in the upper right corner. Since this material was developed by many individuals, there is some variation in adherence to the formats, but in general, similar information appears throughout.

The work breakdown structure (WBS) developed for the GCTI in the three workshops is given in table IV and consists of three major thrusts: (1) observation technologies (WBS 1.0), (2) spacecraft and operations technologies (WBS 2.0), and (3) data and information systems technologies (WBS 3.0). NASA HQ has published a report (ref. 4) describing the needs in these areas. The GCTI technologies proposed by LaRC at these workshops are presented in appendices A, B, and C for each thrust area. Table V summarizes the number of proposals (quad charts) submitted by LaRC in each area and shows the requested funding totals in each fiscal year (FY 90 to 95) as extracted from the quad charts. A summary table listing the proposal titles is given in the appendices before each section of the WBS. LaRC had proposals in all but one WBS element (1.3 Submillimeter). LaRC proposals that were included in the HQ GCTI package (as of July 1989) are indicated in the summary tables within each appendix by a WBS number in the column denoted "NASA GCTI WBS." The technologies eventually chosen for GCTI funding will be selected from those listed in the appendices and from similar proposals made by other NASA centers.

Observation Technologies (WBS 1.0)

LaRC contributed 40 technology proposals in 7 of the 8 observation technology subelements (appendix A). These included entries in the areas of coolers, detectors, microwave sensing, optics, pointing and control, lasers, and calibration. The emphases of the observation technology proposals are primarily to advance maturity of the instruments and to improve overall measurement performance by development of better pointing, control, and calibration techniques. In order to better understand the importance of the LaRC proposals, the following discussion will address the development maturity of the sensing techniques.

Table I presents the broad list of measurements desirable for a global change science program, and the "measurement method" column often lists more than one possible observation approach. To assist in identifying the areas having the greatest technology needs, table II highlights the measurement maturity for each observable. Some sensors have flown operationally; others have flown as experimental systems; and still others are only proposed experiments or, as yet, are unscheduled for development. Thus, it is possible to relate the science needs to technology needs via the measurement technique. Table VI presents in a matrix format the list of the top-level measurement categories cross-referenced to the techniques that have been proposed for each observable. For example, six potential sensing techniques have been identified for measuring the tropospheric ozone concentration. In addition to linking the observable to potential sensing techniques, this table links each technique to the advanced technologies required to enable or enhance it. As can be seen in the lower portion of the table, both the spacecraft and the data and information technologies can be so generally applicable as to enhance all the sensing techniques.

Table VI also shows the resolution and accuracy deemed adequate for each of the variables as proposed by the respondees to LaRC's survey. These numbers are different in some cases from the resolutions offered in table I; this reflects the different applications that various scientists may make of the same observable.

The sensing needs, in general, for a global Earth observation measurement program include the following:

- Laser systems for measuring cloud heights, aerosols, temperature, moisture, chemical composition, and winds
- Instruments for measurements in atmospheric chemistry
- High-resolution atmospheric sounders incorporating visible, infrared, and microwave channels
- Improved active/passive microwave sensors for surface hydrologic studies and precipitation measurements
- Earth radiation flux detectors

The extent of the technology development needed to bring any specific technique to maturity varies, of course, with the technique and its application. The technology readiness of the sensing techniques listed in table VI will now be described using a scale of 1 to 8 as defined in table III.

The authors wish to acknowledge Charles Husson of ST Systems Corp. (STX) for his contributions to the following descriptions of technology readiness of the science sensors.

Light detection and ranging (lidar). Atmospheric physical and chemical properties as measured by laser interactions are well supported by theory and experiment. The design specifications for the components of a lidar system can be readily defined in order to achieve the required instrument performance. However, for the global change era, across-the-board improvements in component technology are required to extend the instrument performance; reduce weight, volume, and power; and comply with spacecraft integration requirements. As a generic instrumentation technology, lidar for global change is at level 3 and has passed through analytical conceptual design tests and in many cases has been demonstrated experimentally. Measurement requirements are being modified to meet the needs of future global change observations, and these inputs will challenge the component development and availability. The Lidar Atmospheric Sensing Experiment (LASE) and the Lidar In-Space Technology Experiment (LITE) provide a basis for the extrapolation to other lidar applications and a framework within which to design future instruments. Improvements under the GCTI in fixed and tunable lasers with optimized wavelengths; in laser wavemeters, filters, and receivers; and in telescopes are the prime requisites for reaching level 4 (critical functions/characteristics demonstrated).

Gas correlation. Gas filter correlation radiometry (GFCR) is based on a well-established laboratory technology to detect gas species by the matched-filtering spectral-absorption properties of a gas in a test cell. While dual-beam spectroscopy has antecedents in sophisticated laboratory apparatus and is used to make passive remote measurements from the ground, aircraft, and spacecraft, the long optical paths and broadband source radiation inherent in remote passive sensing are limiting factors in the global change era. While for global change GFCR can be considered at level 3, current applications such as the Measurement of Air Pollution from Satellite (MAPS) instrument and the Halogen Occultation Experiment (HALOE) instrument will serve as precursors to advance the technology maturity. To meet the requirements for global change observations, further component development is required in detectors and test cell life, stability, and sensitivity; in telescope design; in beam path optics; and in solid-state modulators. With the availability of these improved components, GFCR instrument level 4 can be achieved.

Ultraviolet radiometry—0.01 to 0.450 μm. Using ultraviolet (UV) radiometry to measure solar radiance and the Earth's upper atmosphere has a well-developed basis in science. GCTI program activities will be focused on the development of efficient optical throughput, stable and sensitive detectors, and optical beam devices to enhance information processing. UV radiometry for global change applications has passed the level 2 (conceptual design formulated) readiness state and, for some applications, has been tested in space. For future field-of-view, spatial resolution, and sensitivity requirements, level 3 or 4 can be reached only when components required by the level 2 designs are available and tested. These components include spectrometers, interferometers, lenses, detectors, and information processing components.

Visible radiometry—0.450 to 0.750 μm. Visible radiometry is probably the most widely understood technology in the remote sensing inventory. For the global change era, users will be extending component capabilities to obtain better calibration, spectral resolution, and spatial resolution with their concomitant pointing, motion, and optical implications. Of these, calibration is the most critical. For example, measurement requirements of 10 nm spectral resolution with a system accuracy of 1 percent and 100 m spatial resolution challenge the current technology. While many of the global change science instrument concepts have moved into level 5 readiness (component/breadboard tested in a relevant environment), cost penalties and trade-offs associated with flight such as weight, power, volume, spectral and spatial resolution, motion compensation, sensor calibration, and information data density govern the overall level of technical readiness. In this broad sense, the global change visible radiometer instrument has entered level 4.

Infrared radiometry—0.750 to 2.0 μm. For the pre-global change mission environment, infrared (IR) radiometry from 0.750 to 2.0 μm is a well-developed remote measurement technology. However, for the global change era, there are requirements for increased spatial and spectral resolution, narrower fields of view, and long-term stability of optical and detection components. Also, major efforts are required to reduce weight, volume, and power. Analytical models are required to determine optical cleaning processes, telescope contamination, and heat flow in the field of view. This development work is a precursor for level 4 activity. In fact, there are still some efforts required to complete level 3, but the infrared radiometry instrument technology initiatives in the 0.750 to 2.0 μm regime will primarily be directed to the completion of level 4.

Far infrared radiometry—2.0 to 100 μm. Far infrared (FIR) radiometry instruments have precursors in the Earth Radiation Budget Experiment (ERBE) and the Clouds and Earth's Radiant Energy System (CERES) upon which to build global change broadband instruments. Spectroscopy of the Atmosphere using Far Infrared Emissions (SAFIRE) is a precursor for molecular species measurements in FIR. The GCTI development should provide improvements in broadband detectors, calibration, and narrow-field-of-view telescopes. Also, better models for heat transfer, contamination, and stability are required for testing and analysis. Technology improvements to FIR radiometry are focused on instrument performance, weight, volume, and power for the global change era. Since the GCTI effort will be directed to get the best performance out of the individual component technologies, the instrument performance requirements will depend on the achievable component technology. Completion of level 3 is possible with preliminary results from the GCTI program and from CERES. When component performance is demonstrated, level 4 activities may begin.

Submillimeter wave. Submillimeter heterodyne receiver technology is the only technique capable of providing the required sensitivity and spectral resolution to simultaneously monitor both primary and trace species involved in the destruction of stratospheric ozone. The current state of the art in submillimeter technology covers frequencies up to 200 GHz. The existing gallium arsenide mixers do not have sufficient sensitivity to detect all the species on a global scale. New quantum well or varactor solid-state local oscillators and submillimeter receivers at 1200 and 2000 GHz must be developed for critical observations of OH and HF. Heterodyne receiver technology does not exist for these frequencies. Both photoconductive and superconducting mixers will be pursued, and lower temperature coolers must be available. Overall, the instrument performance, now at level 2, depends on component development matched to global change requirements.

Microwave radiometry. Passive microwave technology has the following factors affecting its future development: instrument development, performance characterization, spacecraft integration requirements, and the analyses of data decomposition algorithms. Requirements in the global change era include more stringent specifications on the lobe effects, surface finishes, and receiver technology. Analysis of complex, asymmetrical, large receiving antennas has not been completed, and resulting antenna designs may create challenging spacecraft integration problems. Further, the receiver technology and information processing concepts are closely linked to the antenna design and performance. For these reasons, much of the microwave radiometry instrument activity is limited primarily to level 2 and partially to level 3. The technical initiatives to bring microwave radiometry into the global change era will address the level 2 and level 3 issues within the context of spacecraft weight, volume, power, and integration limits. Prior to reaching level 4, full-scale tests will be required.

Active microwaves. Active microwave technology has three facets to its readiness level: (1) the complexity of the reflection system, (2) the pointing and control management and implementation system, and (3) the detectors. Because of platform limitations, microwave antenna reflection systems are typically asymmetrical and difficult to analyze or design to obtain the desired improvements in the scanning and ranging requirements. Further, the narrow-field-of-view requirements for global change applications require significant reduction of lobe patterns. This difficulty is further increased by the asymmetry of the antenna system. Detector improvement is less demanding than that required for passive systems. The technology initiatives for global change will be directed at level 2 and level 3 activities. Some full-scale testing will be required to reach level 4.

Active cavity radiometry. Active cavity radiometers require cryogenic coolers in order to achieve the needed improvements in time constants, sensitivity, and field of view. As yet, the detectors, cooling, and calibration components have not been integrated as an instrument package. While the components are mature, the instrument itself must next be brought to level 5 (component/breadboard tested in relevant environment).

In situ. This category implies no particular sensing technique, but will require application of many of the techniques discussed above. Although the stringent requirements placed on an instrument for remote sensing do not generally apply to in situ measurements, the technology advances made in components will surely find applications here as well.

The quad charts in appendix A represent LaRC proposals in the observations thrust.

Spacecraft and Operations Technologies (WBS 2.0)

Although the discussion in the previous section has highlighted the critical issue of sensor maturity and the technology needs of the instruments, many additional supporting technologies must be developed relative to the spacecraft that carries the instruments and to the data-handling systems that store and process the huge volume of information the instruments produce. This section presents the work breakdown structure (WBS) developed to categorize the spacecraft technologies, and the next section addresses the information systems. LaRC contributed 18 quad charts in the 6 spacecraft WBS subelements (appendix B). These included entries in the areas of materials, structures and control, systems analysis, power, propulsion, and thermal control. In three of these areas (WBS 2.4, 2.5, 2.6), the proposals submitted by LaRC were related to nondestructive evaluation (NDE) techniques for monitoring system and component health. In WBS 2.3, the three proposals for systems analyses assume cooperation with other centers, but LaRC proposes to lead these activities and provide funds to others as suballotments from the total funding.

The emphases of technology proposals in this WBS thrust are very broad and address improvements needed in all the spacecraft subsystems as well as in their integration into operational spacecraft that can achieve the performance required by the global change science mission. While the various disciplines (e.g., power, propulsion, and attitude control) continue to advance subsystem and component capabilities, their utilization in flight systems is limited because of a lack of flight qualification history and heritage. It is proposed that a flight qualification program be initiated under the GCTI to carry those particularly promising technologies to flight hardware status. These subsystems and components could then be incorporated into the future system-level designs with reasonable expectations of obtaining acceptance and approval.

Materials. Global change missions require highly efficient platform and experiment support structures with stable geometry, long (5 to 30 years) life, and reliable performance in both geostationary and low Earth orbits. The materials element addresses the need to develop structural and tribological materials and coatings and nondestructive evaluation/inspection technology for reliable long-term performance of high-precision observation systems, reflectors, antennas, and stable platforms.

Structures and controls. The employment of multi-instrument platforms with their stringent pointing accuracy and stability specifications required by global change science dictates the development of new structures and control technologies. The structures and control element addresses the issues associated with potentially large and flexible platform structures and reflectors (erectable and deployable) and pointing, dynamics, and control.

Systems. The proposed Mission to Planet Earth (MPE) presents unprecedented challenges in all spacecraft and sensor system areas as well as in integration and on-orbit verification of all these systems to effect an operational spacecraft. The systems element provides the methodologies, tools (software, graphics, workstations), and studies needed to conduct spacecraft/platform/sensor system- and subsystem-level design and evaluations. Such studies assess the relative merits that various space infrastructures, competing technologies, or operational strategies might have. An MPE architectural system study now underway will compare the performance and complexity of placing subsets of the global change sensors in low Earth orbit, geostationary orbit, or other intermediate orbits. A second system study is examining the performance of geostationary platform concepts to achieve the pointing and stability requirements for a complement of 18 typical instruments proposed for global change science. This study will quantify the sources of performance limitations and the benefits that can be derived from application of various advanced technology options.

Other studies include requirements for autonomous and adaptive on-orbit integration, certification, and verification; requirements for automated assembly and checkout of large platforms; and assessment of space environmental effects on systems.

Power, propulsion, thermal control. The LaRC proposals in these areas represent various applications of nondestructive evaluation techniques to improve the monitoring and diagnosis of system and component health.

The elements in the spacecraft/operations technology program include analysis, design, development, integration, test, and verification of components and systems and the use of ground and flight tests and operations. These activities should result in better prediction of system performance, lower risk, and greater confidence in meeting mission objectives.

The quad charts in appendix B represent LaRC proposals in the spacecraft and operations thrust.

Data and Information Systems Technologies (WBS 3.0)

The data volume and data rates that will be produced by the instruments proposed for a global change science program will greatly exceed all previous science programs. The supporting information system must provide end-to-end services including data acquisition, storage and communication, and delivery to the user community. LaRC contributed 24 quad charts in the 4 WBS subelements (appendix C). These included entries in the areas of systems, flight element, information transfer, and ground element technologies. The emphases of the technologies in this thrust are very broad and address such diverse issues as flight and ground element hardware, software, and architectures, as well as software development environments, networks, and user interfaces.

Systems technology. A review of the information system maturity reveals the need for improvement in several key areas: application of standards at command, data, and interface development; use of software engineering approaches for creation of software at all levels, including flight, ground, and user applications; development of integrated tool sets that cover the entire development life cycle for both hardware and software (design, rapid prototyping, performance evaluation, integration, test, and calibration); use of test beds for determining reliability of hardware and software designs; creation of reusable software packages; and the application of automation for reducing the burden of continuous mission operations.

Flight element technologies. The performance of the orbiting sensors, in terms of system reliability, adaptability, and data quality, can be improved by using processing elements specifically matched to individual sensors. Such sensor preprocessing takes advantage of intimate knowledge of the sensor characteristics and optimizes use of the spacecraft resources while still delivering data in a generic format suitable for shared processing. The technologies holding the most promise include advanced neural networks, optical preprocessors, hybrid digital processors, and chip-level integration. Very Large Scale Integration (VLSI) technologies will be required to deliver components that meet the constraints of weight, power, and size. In addition, the onboard data system used to gather, store, and deliver science data can be improved to reduce data flow bottlenecks. The significant technologies in this area include high data rate, large volume storage systems; data compression and autonomous target-of-opportunity techniques; and interconnect systems with low electromagnetic interference susceptibility.

Information transfer. The highest priority technologies needed for development of the high-performance, space-based communications systems will be those that enable use of the wideband optical frequencies and high accuracy beam pointing. These include improvements in laser power output and receiver sensitivity and will result in smaller antennas, improved packaging, and reductions in spacecraft disturbance torques, size, weight, and power. The ground segment requires improvement in those technologies that enable broad distribution and data access to principal investigators and end users. Specifically, high-performance networks and microwave ground terminals are needed for access to data archives and supercomputing resources so that communications network performance will be commensurate with recent advances in optical storage and scientific workstation performance.

Ground element technologies. Maximizing the scientific return from the collected data is the broad emphasis of this area. The multidisciplinary nature of Earth system science will require scientists to study data sets outside their normal areas of expertise and to process and understand the implications of the data. Obvious technology needs will include the advancement of mass storage devices, high-performance parallel processors, and information extraction techniques that can accommodate the huge volume of science data. In addition, smart user interfaces will be needed to support data query, filtering, and visualization, and to enable scientists to collaborate with others to fuse data for comprehension. Special purpose processors will also be needed for efficient processing of sensor- or problem-specific algorithms, and improvement in modeling techniques will be required to reconstruct and simulate the Earth processes identified under this science program.

The quad charts in appendix C represent LaRC proposals in the data and information systems thrust.

4. Programmatic Assessment

The 82 LaRC proposals summarized in table V were submitted during the course of 3 workshops held to develop the GCTI WBS and to prioritize technologies. Fifty-nine of these were still included, in some form, within the full GCTI quad package distributed in late June 1989 by NASA, OAST. The GCTI has been envisioned as having three emphases for its technology developments (table VII). In phase 1, those technologies that support or provide needed alternatives for the near-term Earth Observing System (EOS) will be included under EOS technology. In phase 2, those technologies applicable to other low Earth (LEO) or geostationary-orbiting (GEO) sensors and spacecraft will be included under LEO/GEO technologies. These two phases are the only ones currently proposed for the FY 91 funding start. Phase 3 technologies are those specifically dictated by a future Mission to Planet Earth infrastructure and will be identified at a future time.

Budget realities will likely dictate that all of LaRC's proposals cannot be accommodated within GCTI. However, some of these proposals may be addressed under existing OAST base funding or focused research and technology programs. In any event, the role that LaRC plays in the future global change program must be shaped by a conscientious effort by LaRC management to acquire the resources and to prioritize the programs that it feels will serve the nation and NASA best.

5. Concluding Remarks

Global change is a documented reality and a focus of international scientific and policy concern. The greenhouse effect, ozone depletion, and acid rain have heightened worldwide awareness of the need for a better understanding of the Earth's atmosphere and its dynamic interactions with the land and oceans. A brief overview has been given of the global change science issues and their related measurements. The science requirements and candidate sensors for each measurement have been summarized. Technologies that enable or enhance these measurements have been proposed as part of the Langley Research Center (LaRC) technology development program. Detailed descriptions have also been given for each proposed technology, including the scope, objective, and approach for that candidate; a technology readiness timeline; a list of deliverables; and an estimate of the resources needed to meet the deliverables milestones. This report, documenting the products of the LaRC Global Change Technology Initiative (GCTI) Task Force, will be provided to NASA Headquarters to support their efforts to develop a GCTI program. In addition, it is hoped that the areas of technology advancement highlighted by this report will motivate research and development by industry and universities so that the gap between the desire for and the reality of global change understanding will be narrowed.

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Appendix A
Observation Technology Proposals (WBS 1.0)

LaRC GCTI Observation Technologies

1.1 Coolers

Technology	NASA GCTI WBS	Proposal funding requirements, millions of dollars					
		FY90	FY91	FY92	FY93	FY94	FY95
Leak monitor for refrigerants			0.1	0.1	0.1	0.2	0.2
Totals			0.1	0.1	0.1	0.2	0.2

E. MADARAS

Leak Monitor for Refrigerants

SCOPE
DEVELOP FIBER OPTIC SENSORS THAT CAN BE USED TO LOCATE LEAKS IN AMMONIA-BASED REFRIGERANT SYSTEMS.

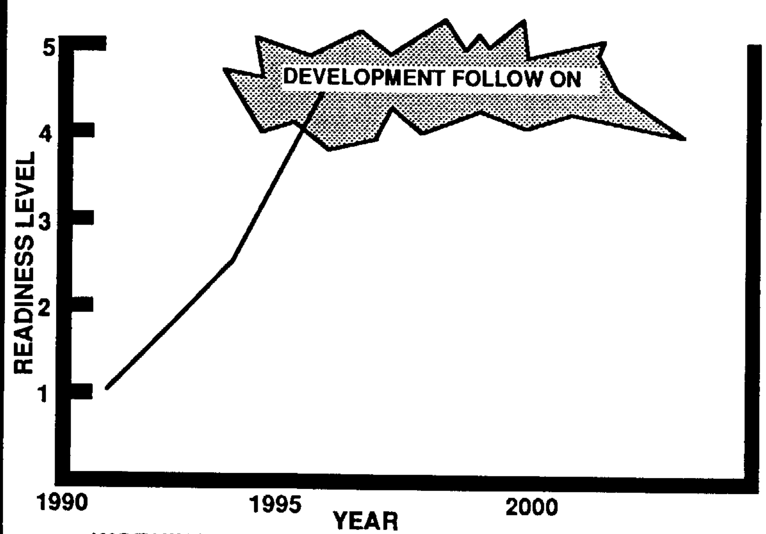
OBJECTIVE
- PROVIDE REAL-TIME INFORMATION ABOUT THE LOCATION OF AMMONIA-BASED REFRIGERANTS.

RATIONALE
- MONITOR REFRIGERATION SYSTEM FOR AMMONIA LEAKS.
- A SYSTEM IS NEEDED THAT CAN MONITOR THE REFRIGERATION SYSTEM WHILE IT IS UNDER CONSTRUCTION AS WELL AS ON ORBIT.

APPROACH
- DEVELOP FIBER OPTIC COATINGS THAT ARE SPECIFICALLY SENSITIVE TO THE AMMONIA-BASED REFRIGERANT MATERIAL.
- DEVELOP THE MEASUREMENT SYSTEM THAT CAN BE USED TO MEASURE THE SPECIAL FIBER FOR LEAKS.

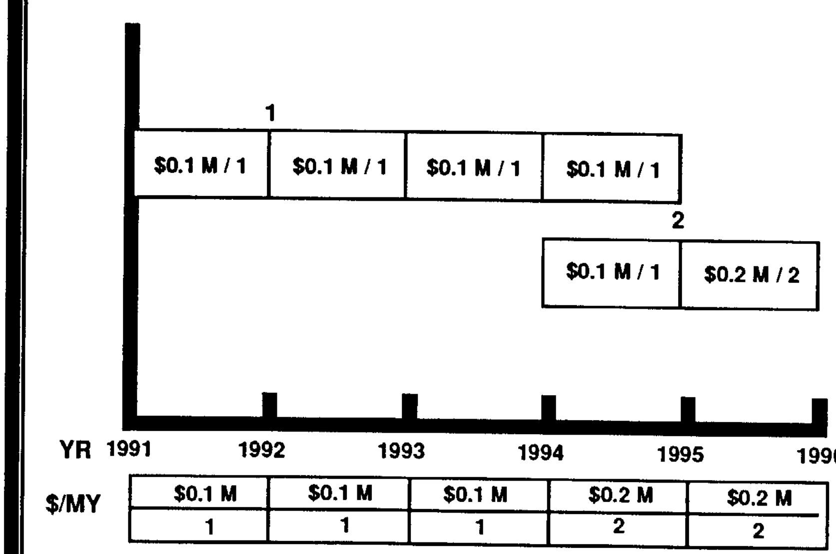
DELIVERABLES
1. A SPECIFICALLY DESIGNED FIBER WITH COATING THAT IS SENSITIVE TO THE PRESENCE OF THE REFRIGERANT THAT IS TO BE USED.
2. DEVELOP A PROTOTYPE SYSTEM TO MONITOR THE FIBER SYSTEM FOR THE PRESENCE OF THE REFRIGERANTS.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



LaRC GCTI Observation Technologies

1.2 Detectors

Technology	NASA GCTI WBS	Proposal funding requirements, millions of dollars					
		FY90	FY91	FY92	FY93	FY94	FY95
Long-life detector arrays	1.21	0.5	1.0	0.8	0.8	1.0	1.0
InGaAs avalanche photodiodes	1.22	.2	.4	.4	.4	.4	.2
Multiquantum well infrared detectors	1.22	.2	.4	.4	.4	.4	.2
Broadband sensor technology	1.24	.125	.125	.125	.125	.25	.25
Far infrared technology	1.25	.5	1.1	1.0	1.0	1.0	0
Detector arrays for smart sensing	1.26		.5	2.0	2.0	1.0	0
Chip-level integration of sensor preprocessing	3.21-1		2.0	3.0	3.0	3.0	3.0
Smart sensors			.5	1.0	1.0	1.0	0
Totals		1.525	6.025	8.725	8.725	8.05	4.65

W. MILLER

INFRARED DETECTOR TECHNOLOGY - LONG-LIFE DETECTOR ARRAYS

SCOPE

DEVELOP LONG-LIFE INFRARED DETECTOR ARRAY TECHNOLOGY TO SUPPORT GLOBAL CHANGE MEASUREMENTS OF ATMOSPHERIC CONSTITUENTS AND TEMPERATURE.

OBJECTIVE

INCREASE RELIABILITY AND OPERATING LIFETIME OF DISCRETE AND ARRAYED DETECTORS.
INCREASE SPECTRAL COVERAGE OF PHOTOCONDUCTIVE (PC) AND PHOTOVOLTAIC (PV) ARRAYS.

RATIONALE

HgZnTe HAS DEMONSTRATED INCREASED STRENGTH AND RESISTANCE TO THERMAL DRIFT.
DEVELOPMENT OF LONG-LIFE DISCRETE AND ARRAY IR DETECTORS ON HgZnTe COVERING THE MID-IR (3-5 MICRONS) AND FAR-IR (8-20 MICRONS) WILL ENABLE MISSION LIFETIMES OF GREATER THAN FIVE YEARS.

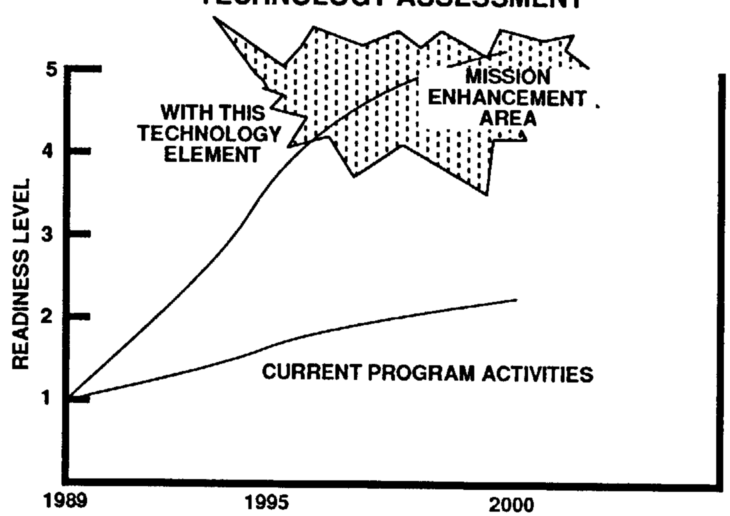
APPROACH

DEVELOP HgZnTe MATERIALS AND DEVICE TECHNOLOGY THROUGH THE USE OF SOLID-STATE RECRYSTALLIZED AND LIQUID EPITAXIAL GROWN SUBSTRATES. PERFORM LIFETIME TESTS ON PC AND PV DETECTORS IN DISCRETE AND ARRAY FORMATS FABRICATED BY LIQUID EPITAXY, METALLO-ORGANIC CHEMICAL VAPOR DEPOSITION (MOCVD), AND MOLECULAR BEAM EPITAXY (MBE) TECHNIQUES.

DELIVERABLES

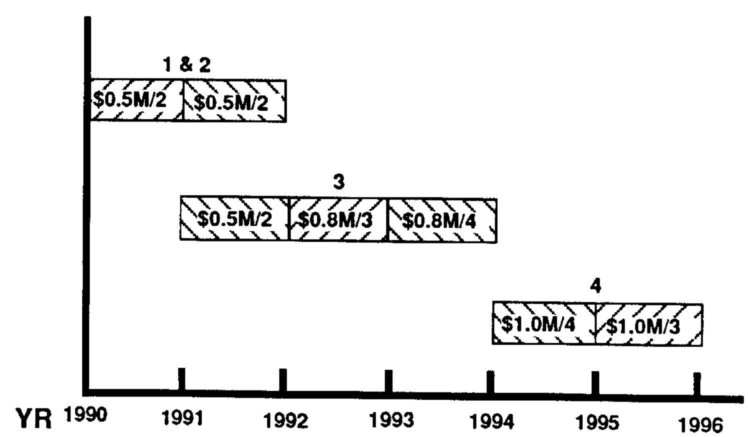
1. HgZnTe SUBSTRATES COVERING 3-5 AND 8-20 MICRON SPECTRAL REGIONS AND SUPERIOR ELECTRO-OPTICAL (E-O) AND MECHANICAL PROPERTIES.
2. PC AND PV TEST SAMPLES.
3. PROTOTYPE LINEAR AND AREA ARRAYS.
4. MONOLITHIC LINEAR AND AREA ARRAYS.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



NASA-LaRC

W. MILLER

INFRARED DETECTOR TECHNOLOGY - InGaAs AVALANCHE PHOTODIODES

SCOPE

DEVELOP InGaAs AVALANCHE PHOTODIODE (APD) INFRARED DETECTOR ARRAY TECHNOLOGY TO SUPPORT GLOBAL CHANGE LIDAR MEASUREMENTS OF ATMOSPHERIC CONSTITUENTS.

OBJECTIVE

INCREASE SPECTRAL COVERAGE OF AVALANCHE PHOTODIODES.
INCREASE SENSITIVITY AND OPERATING LIFETIME OF DISCRETE AND ARRAYED LIDAR DETECTORS.

RATIONALE

ENABLES ACCURATE GLOBAL MEASUREMENTS OF ATMOSPHERIC AEROSOLS AND OTHER IMPORTANT TRACE CHEMICALS WITH EYE-SAFE LIDAR.

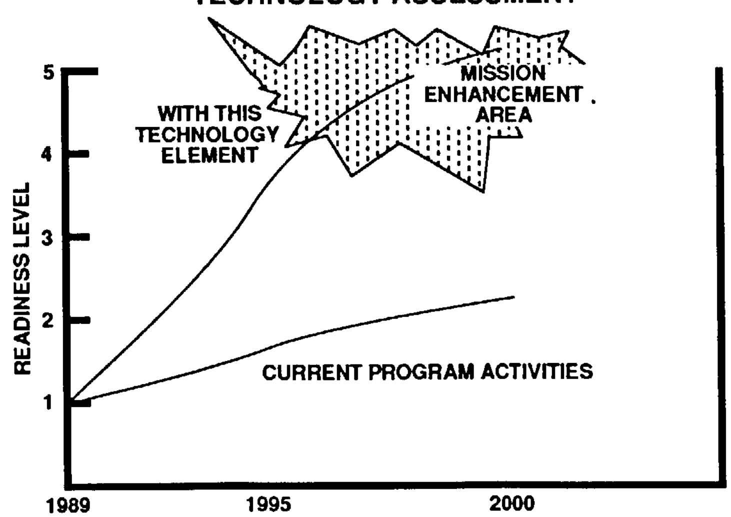
APPROACH

DEVELOP InGaAs AVALANCHE PHOTODIODE MATERIALS AND DEVICE TECHNOLOGY THROUGH THE USE OF METALLO-ORGANIC CHEMICAL VAPOR DEPOSITION (MOCVD) EPITAXIAL GROWN SUBSTRATES. PERFORM PERFORMANCE AND LIFETIME TESTS ON APD DETECTORS IN DISCRETE AND ARRAY FORMATS FABRICATED BY MOCVD EPITAXY.

DELIVERABLES

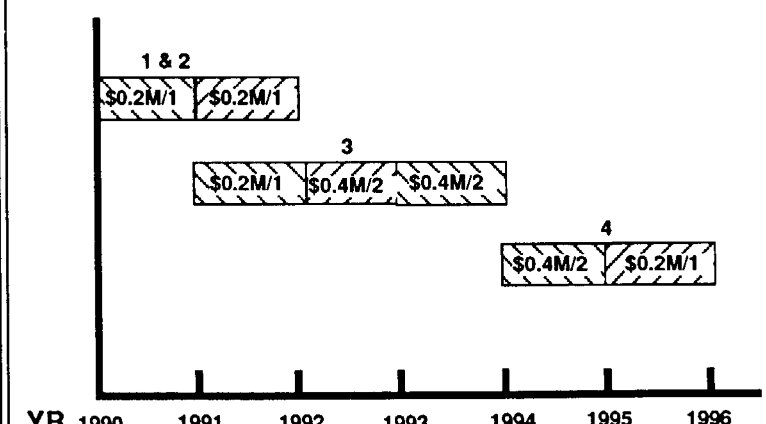
1. InGaAs SUBSTRATES TO 2 MICRONS WITH SUPERIOR E-O AND MECHANICAL PROPERTIES.
2. AVALANCHE PHOTODIODE TEST SAMPLES.
3. PROTOTYPE LINEAR AND AREA ARRAYS.
4. EVALUATION OF LINEAR AND AREA ARRAYS.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



NASA-LaRC

W. MILLER

INFRARED DETECTOR TECHNOLOGY - MULTIQUANTUM WELL IR DETECTORS

SCOPE

DEVELOP AlGaAs MULTIQUANTUM WELL INFRARED PHOTODIODE DETECTOR ARRAY TECHNOLOGY TO SUPPORT GLOBAL CHANGE LIDAR MEASUREMENTS OF ATMOSPHERIC CONSTITUENTS.

OBJECTIVE

INCREASE SPECTRAL COVERAGE OF MULTIQUANTUM WELL PHOTODIODES.
INCREASE SENSITIVITY AND OPERATING LIFETIME OF DISCRETE AND ARRAYED LIDAR DETECTORS.

RATIONALE

ENABLES ACCURATE GLOBAL MEASUREMENTS OF ATMOSPHERIC CO AND OTHER IMPORTANT TRACE CHEMICALS WITH EYE-SAFE LIDAR.

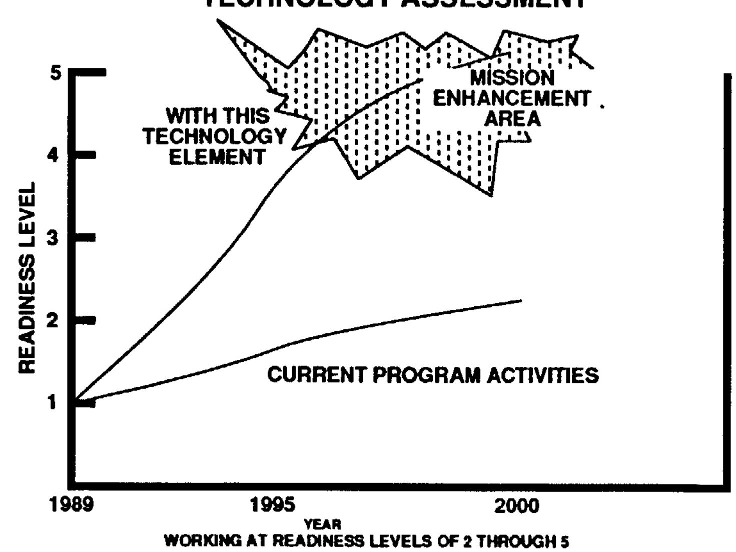
APPROACH

DEVELOP AlGaAs MULTIQUANTUM WELL PHOTODIODE MATERIALS AND DEVICE TECHNOLOGY THROUGH THE USE OF MOLECULAR BEAM EPITAXY (MBE) EPITAXIAL GROWN PROCESS. PERFORM QUANTUM CHARACTERIZATION AND LIFETIME TESTS ON MULTI-WELL DETECTORS IN DISCRETE AND ARRAY FORMATS.

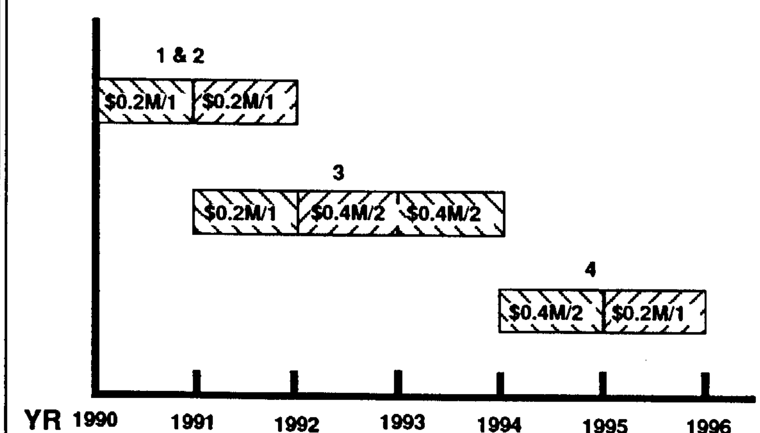
DELIVERABLES

1. AlGaAs OPTIMIZED FOR 4.7 MICRONS WITH SUPERIOR E-O AND MECHANICAL PROPERTIES.
2. MULTIQUANTUM PHOTODIODE TEST SAMPLES.
3. PROTOTYPE LINEAR AND AREA ARRAYS.
4. EVALUATION OF LINEAR AND AREA ARRAYS.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



NASA-LaRC

ADVANCED SENSOR CONCEPTS–BROADBAND SENSOR TECHNOLOGY

SCOPE

DEVELOP A HIGH SENSITIVITY, BROAD SPECTRAL BAND DETECTOR FOR USE IN SPACEBORNE EARTH RADIANCE MEASUREMENT SYSTEMS.

OBJECTIVE

PROVIDE RADIANCE MEASUREMENTS OF THE EARTH'S REFLECTED AND EMITTED ENERGY IN SEVERAL WIDE SPECTRAL BANDS WITH HIGH ACCURACY AND PRECISION.

RATIONALE

PRESENT TECHNOLOGY FOR EARTH RADIANCE MEASUREMENTS HAS PUSHED THE USE OF DETECTOR MATERIALS (E.G., THERMISTOR BOLOMETER, PYROELECTRIC DETECTOR) TO THEIR LIMIT. A NEW SENSOR MATERIAL WITH HIGH SENSITIVITY AND WIDE SPECTRAL RESPONSE IS NEEDED IN SCANNING AND/OR ARRAY SYSTEMS TO PROVIDE THE NEEDED GROUND RESOLUTION FROM ORBIT.

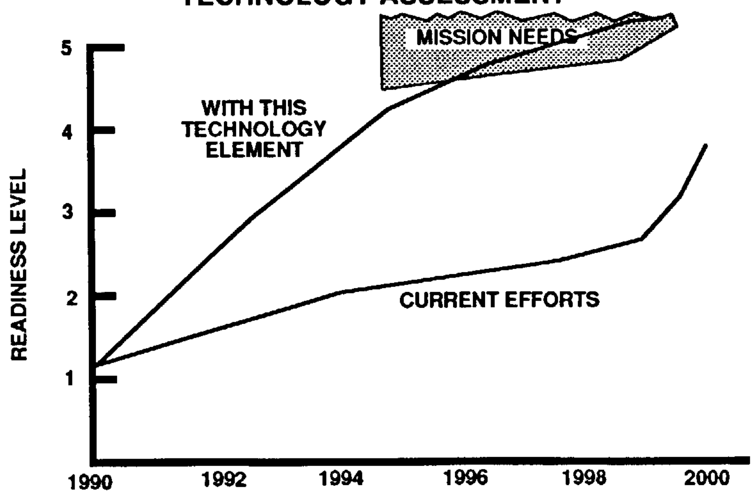
APPROACH

EXAMINE MATERIALS POSSESSING HIGH RESPONSE TO LOW LEVELS OF RADIANT ENERGY THAT CAN BE FASHIONED INTO HIGHLY SENSITIVE, SMALL ELEMENT DEVICES (EITHER SINGLE ELEMENT OR ARRAYS). DETERMINE THAT THESE DEVICES CAN BE OF UNIFORM SPECTRAL SENSITIVITY OVER THE RANGE OF 250 nm to GREATER THAN 50,000 nm.

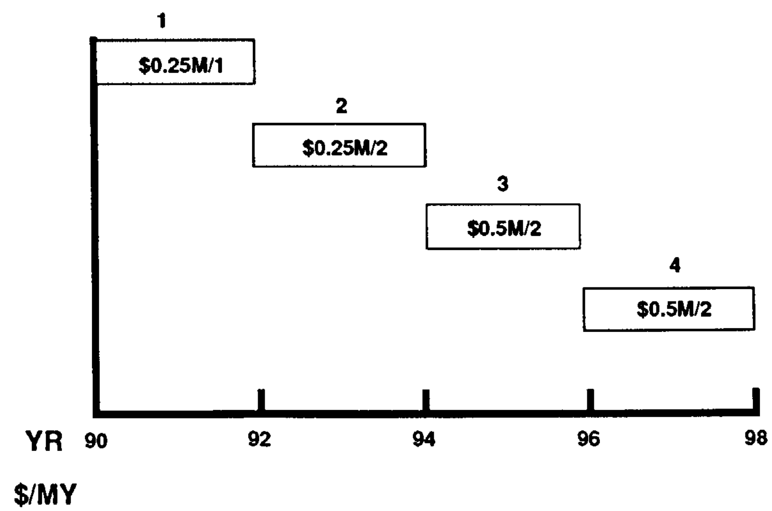
DELIVERABLES

1. EXAMINE MATERIALS POSSESSING POTENTIALLY HIGH SENSITIVITY AND WIDE SPECTRAL RESPONSE.
2. SELECT THE MOST PROMISING GROUP OF MATERIALS TO BEGIN INVESTIGATIONS ON A DETAILED SCALE.
3. PRODUCE A PROTOTYPE SENSOR AND CHARACTERIZE ITS OPERATING PARAMETERS.
4. DETERMINE REQUIREMENTS AND CHARACTERISTICS OF FABRICATING AN ARRAY DEVICE.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



I. NOLT

ADVANCED SENSOR CONCEPTS-FAR INFRARED TECHNOLOGY

SCOPE

DEVELOP FAR INFRARED REMOTE SENSING TECHNOLOGY TO SUPPORT GLOBAL MEASUREMENT OF HYDROXYL (OH) AND ENABLE ENHANCED GLOBAL MEASUREMENT OF WATER VAPOR IN THE ATMOSPHERE.

OBJECTIVE

- ADD NEW MEASUREMENT CAPABILITIES.
- EXPAND DYNAMIC RANGE OF MEASUREMENTS.
- FILTER EARTH RADIATION NOISE.

RATIONALE

ENABLES ACCURATE MEASUREMENT OF THE MOST REACTIVE CHEMICAL SPECIES (OH) AND OTHER IMPORTANT REACTANTS IN THE STRATOSPHERE.

APPROACH

DEVELOP NARROW BAND FILTER TECHNOLOGY THROUGH THE USE OF PHOTOLITHOGRAPHED ETCHED METAL ETALON FILTERS TO REDUCE THE INFLUENCE OF THE BACKGROUND IR RADIATION FROM EARTH.

DELIVERABLES

1 TECHNOLOGY TO PRODUCE METAL ETALON FILTERS.

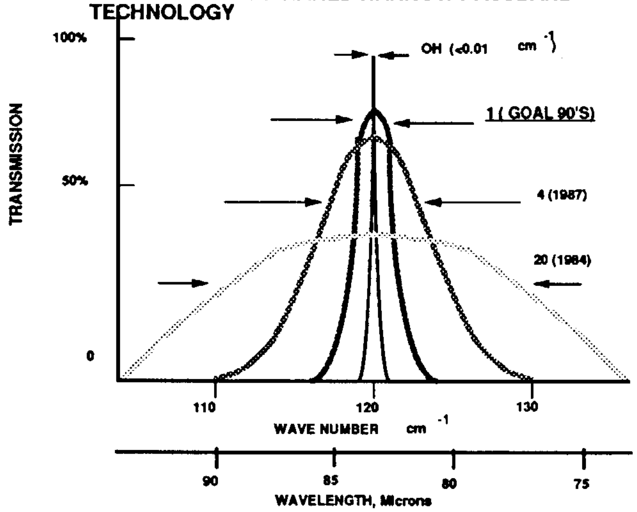
2 TEST SAMPLES AND EVALUATION MODELS.

3 MODELING AND COOLING TECHNIQUES.

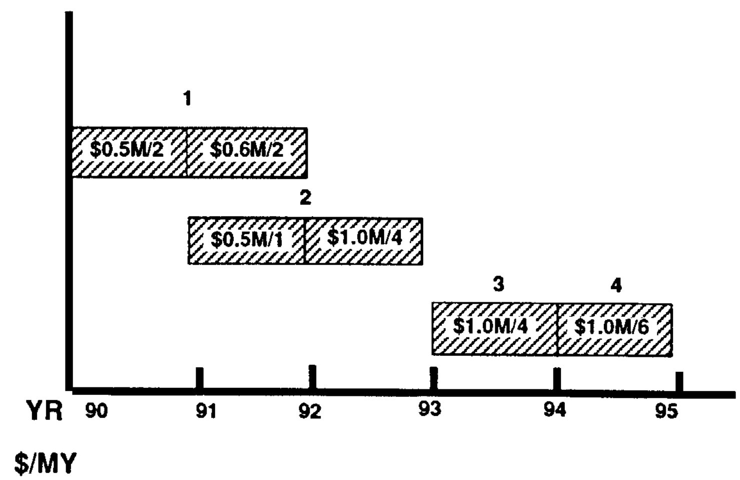
4 EVALUATION OF FILTERS IN HIGH BACKGROUND EXPERIMENTS.

TECHNOLOGY ASSESSMENT

EVOLUTION OF INFRARED NARROW PASSBAND TECHNOLOGY



DEVELOPMENT PLAN



A. JALINK

DETECTOR ARRAYS FOR SMART SENSING

SCOPE

DEVELOP MID-IR CHARGE-COUPLED DEVICE (CCD) DETECTOR ARRAY TECHNOLOGY FOR SCAN MODE, RESOLUTION ZOOM, AND SPECTRAL BAND COVERAGE ABILITY.

OBJECTIVE

OBTAIN ON-ORBIT SMART SENSING CAPABILITY FOR IMPROVED ATMOSPHERIC EPISODE PRECURSOR DETECTION AND MEASUREMENT. MID-IR (6-16 MICRON) DETECTOR ARRAYS WHICH ALLOW POWERFUL ELECTRO-OPTICAL MEASUREMENT ARCHITECTURES, AS THOSE RECENTLY ACCOMPLISHED BY SI-CCD FOR VIDEO PROCESSING.

RATIONALE

MID-IR CCD ARRAYED DETECTORS HOLD PROMISE FOR EVENT SENSING. EXAMPLES ARE ELECTRONICALLY ADJUSTABLE: FOV ZOOM; FOV SCAN MODES; SPECTRAL SCAN AND SELECT; INTEGRATION; SAMPLE/HOLD; DETECTOR BIAS PRELOAD.

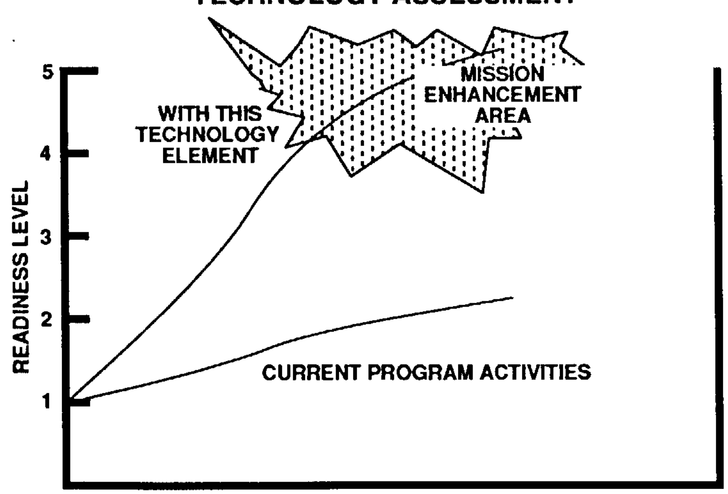
APPROACH

DETERMINE PRECURSOR EPISODE STRATEGIES, AND SET 'SMART' SENSING DETECTION ARCHITECTURE. DEVELOP CCD/DETECTOR PROCESSES, MATERIALS, AND DETECTOR ARCHITECTURE. DEVELOP PROTOTYPE DETECTOR AND LABORATORY DEMO OF APPROACH.

DELIVERABLES

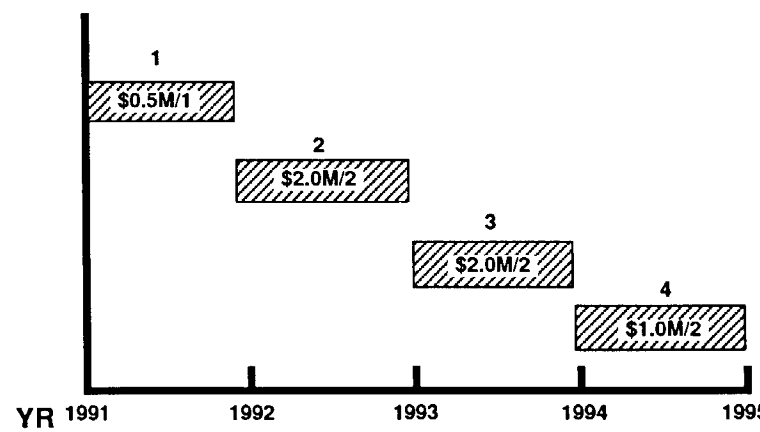
1. REQUIREMENTS AND DETECTOR ARCHITECTURE DEFINITION.
2. CCD/DETECTOR TECHNOLOGY DEVELOPMENT PLAN.
3. DELIVERY OF LABORATORY SAMPLE ARRAYS.
4. DEMONSTRATE TECHNOLOGY AND APPLICATIONS.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



NASA-LaRC

S. JURCZYK

CHIP-LEVEL INTEGRATION OF SENSOR PREPROCESSING

SCOPE

Develop extremely low-power custom sensor preprocessing chip to prepare output of large detector arrays and develop enhanced detector modules with integrated (on chip) pre-processing elements for onboard image and spectral data extraction.

OBJECTIVE

- Enable use of large detector arrays within power constraint.
- Develop high-speed (wide bandwidth) space-qualified preprocessor systems.
- Increase system reliability.
- Improve performance including stability.

RATIONALE

Preprocessing for emerging detector technologies and large detector arrays cannot be accomplished using discrete components. Low-power, space-qualified custom integrated circuits will be required to meet performance speed, power, weight, and volume constraints.

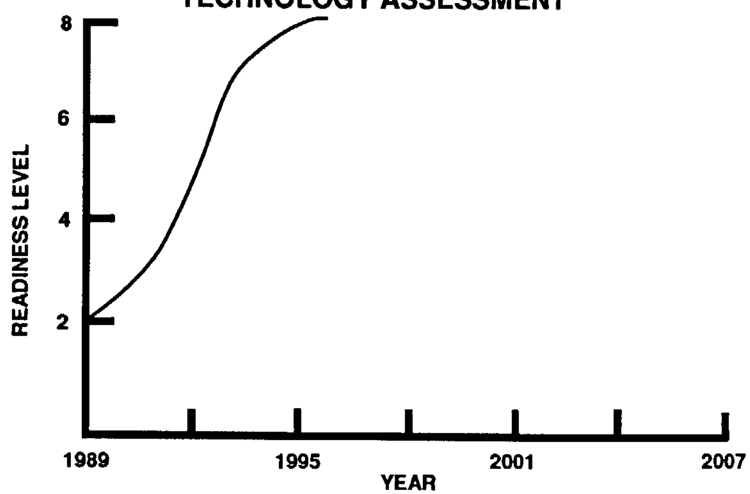
APPROACH

- Analyze preprocessing needs for strawman GCTI sensors.
- Identify suitable semiconductor processes and foundries.
- Develop custom integrated circuit approach.
- Design, fabricate, and test custom circuit.
- Integrate custom circuit into system and test.

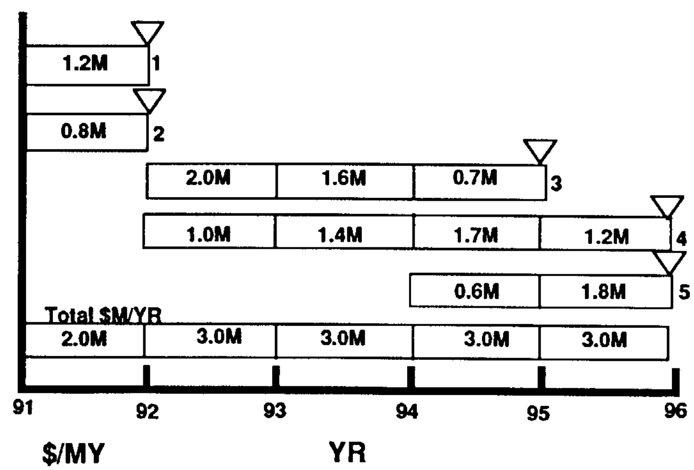
DELIVERABLES

- Report on detector preprocessing requirements.
- Report on custom integrated circuit methodology and suitable processing and foundries.
- Candidate integrated circuit designs.
- Fabricated and tested candidate circuits.
- Demonstration in system testbed.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



S. JURCZYK

ADVANCED SENSOR CONCEPTS--SMART SENSORS

SCOPE

DEVELOP SENSOR SYSTEMS AND PROCESSES TO TRANSFER SELECTED GROUND COMMAND FUNCTIONS TO ORBIT.

OBJECTIVE

- MISSION EXPANSION.
- SYNERGISM WITHIN A MISSION.
- GROUND COMMANDS TO ORBIT.
- CAPTURE OF SHORT-TERM PHENOMENON.

RATIONALE

PROVIDES REAL-TIME RESPONSE FOR DYNAMIC PROCESSES AND A GLOBAL CONTEXT FOR NARROW-FIELD-OF-VIEW, HIGH-RESOLUTION INSTRUMENTS.

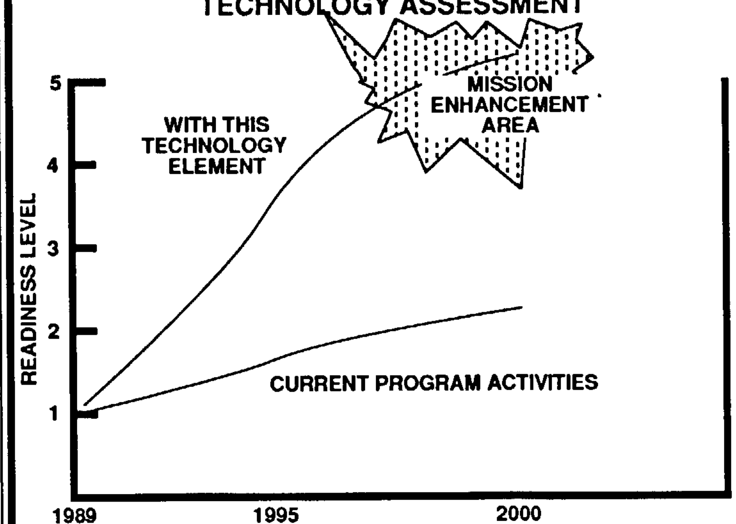
APPROACH

FUNCTIONALITY DEFINITIONS WITH MAN IN THE LOOP PROVIDE AN EARLY ENTRY INTO THIS TECHNOLOGY. MISSION GOALS, SYSTEM ARCHITECTURE, AND STATE-OF-THE-ART HARDWARE WILL DETERMINE THE FINAL ARCHITECTURE AND ALGORITHM DEVELOPMENT TO BE PURSUED UNDER THIS ELEMENT. RECONFIGURATION IS A TOOL TO ACHIEVE THE TECHNICAL OBJECTIVE OF THIS EFFORT.

DELIVERABLES

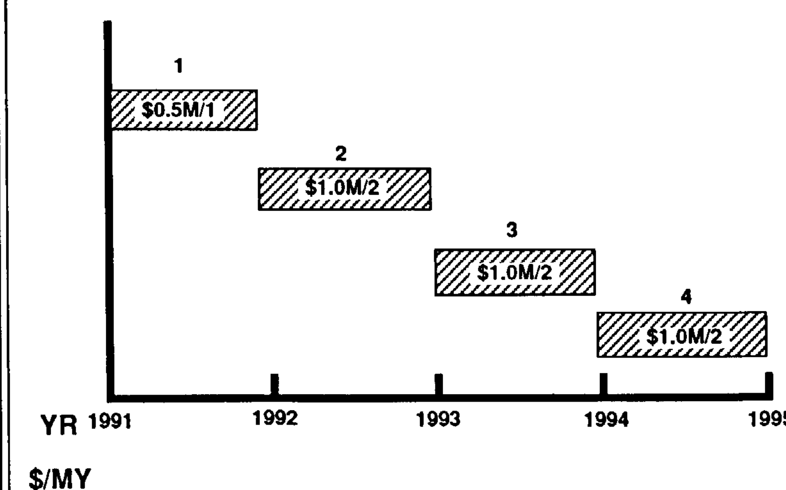
1. FUNCTIONALITY DEFINITIONS.
2. ARCHITECTURE AND ALGORITHM DEFINITIONS.
3. RECONFIGURATION METHODOLOGIES.
4. DEMONSTRATIONS.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



LaRC GCTI Observation Technologies

1.4 Microwave Sensing

Technology	NASA GCTI WBS	Proposal funding requirements, millions of dollars					
		FY90	FY91	FY92	FY93	FY94	FY95
Precision membrane reflector	1.41		2.8	4.1	3.7	3.0	2.3
Distributed phased array	1.41		1.25	2.05	1.85	1.55	0.65
Large space antenna	1.41		0.95	1.8	1.35	0.50	0.30
Measurement/calibration	1.41	0.50	2.0	1.50	0.50	0.50	0.50
Electronically scanning	1.42		0.90	2.00	2.80	2.50	2.00
Characterization of reflector materials	1.42		0.20	0.40	0.40	0.10	0
RF interference rejection	1.42	0.40	0.40	0.60	0.90	1.20	0
Precision ranging radar			0.10	0.10	0.20	0.20	0
Totals		0.90	8.60	12.55	11.70	9.55	5.75

PRECISION, MEMBRANE REFLECTOR ANTENNA TECHNOLOGY (<40 GHZ)

SCOPE Evaluation and development of new and innovative antenna concepts such as mesh deployables and work of Contraves and LeGard on inflatables should be continued and augmented with feed arrays for surface error compensation and rapid beam scanning. Also, the technology for calibration of electrically large antennas, including stable loads, splash plates to cold space, etc., and control and reference systems for pointing control of scanning antennas, needs to be developed.

OBJECTIVES

Develop lightweight mesh deployable or inflatable antennas for frequencies below 40 GHz with diameters up to 100 m for Earth remote sensing. Provide means of calibrating radiometer systems involving large scanning antennas where variations in antenna properties (boresight, pattern shape, side lobe levels and directions) occur on significantly short time scales, and where many of the antenna properties lie outside the normal radiometer calibration loops.

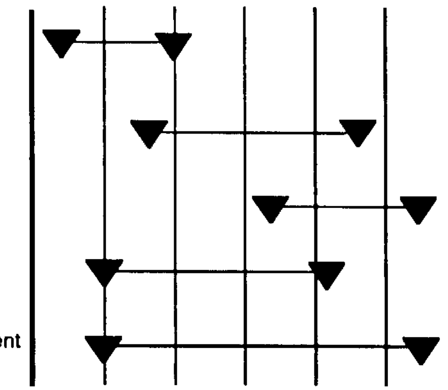
RATIONALE

Precipitation, winds, soil moisture, and snow measurements require frequencies from 2-37 GHz with reflectors from 15-100 m. The low surface tolerances allow the use of mesh and inflatable reflector antennas. Size requires some sort of deployment. Adaptive RF surface distortion compensation techniques are required for onboard compensation of reflector surface errors. Development of new near field measurement technique is mandatory to characterize the RF performance of these large antennas.

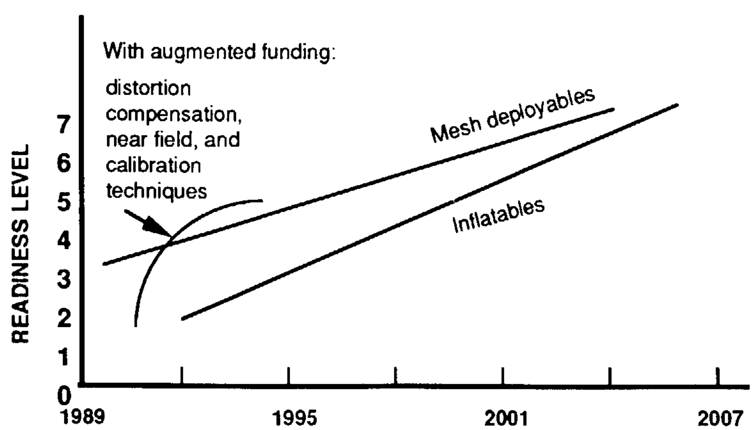
APPROACH Develop precision, membrane antenna technology. Develop accurate computer models of error sources involved in dynamic, on-orbit calibration of large antenna radiometer systems. Errors contributed by various possible methods of viewing cold space when the antenna cannot be slewed to view space directly.

DELIVERABLES

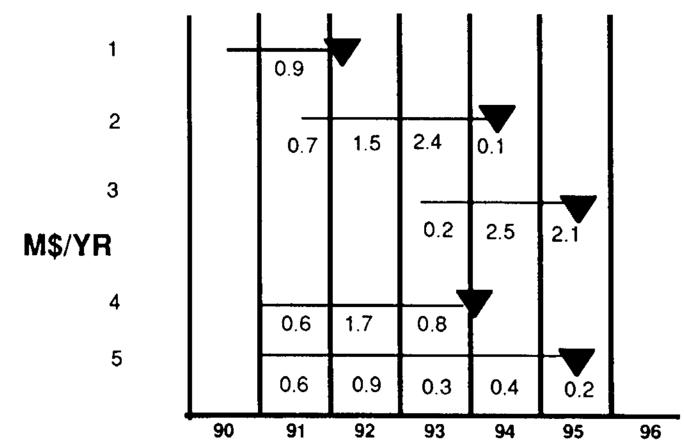
1. Study contracts - different concepts
2. Concept selection - development
3. Proof of concept demonstration
4. Distortion compensation technique (RF)
5. Near field measurement and calibration techniques



TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



TOTAL M$/YR	90	91	92	93	94	95	96
		2.8	4.1	3.7	3.0	2.3	

DISTRIBUTED PHASED ARRAY ANTENNA TECHNOLOGY (40-220 GHz)

SCOPE To demonstrate technology feasibility of large distributed phased array antennas for spaceborne radar applications for frequency range >40 GHz.

OBJECTIVES Capabilities needed:

- Large size (10-20 m long, 1-4 m wide)
- Lightweight (<1000 kg)
- Maintaining aperture flatness of 0.08 cm at 35 GHz
- Scan angle of 60°
- Array surface distortion compensation techniques (RF)
- Polarization purity of 25 to 30 dB

RATIONALE

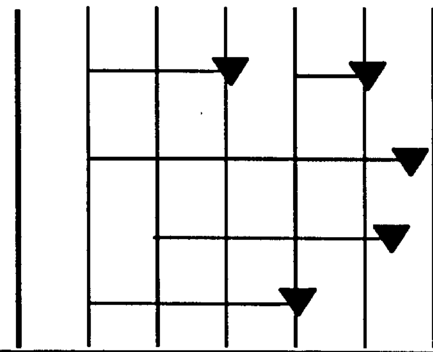
Lighter and less power consuming, large distributed phased array antennas are needed at high frequencies in order to achieve adequate resolution for sufficiently large coverage areas. Currently, there are no phase array antennas larger than 3 meters at frequencies higher than X-band.

APPROACH

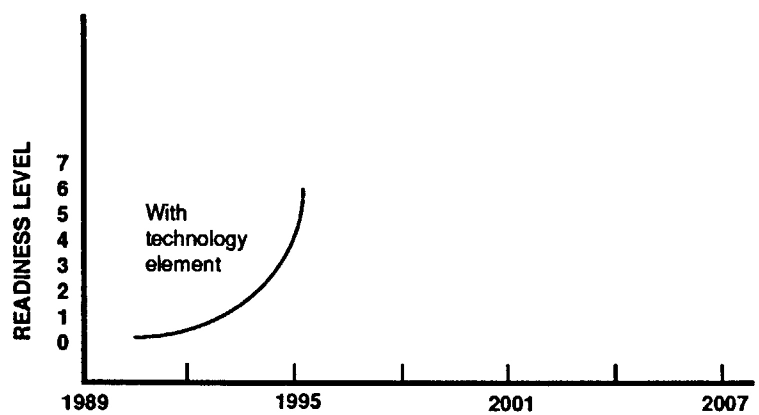
Extend Spaceborne Imaging Radar-C (SIR-C) capabilities to higher frequencies and higher resolutions.

DELIVERABLES

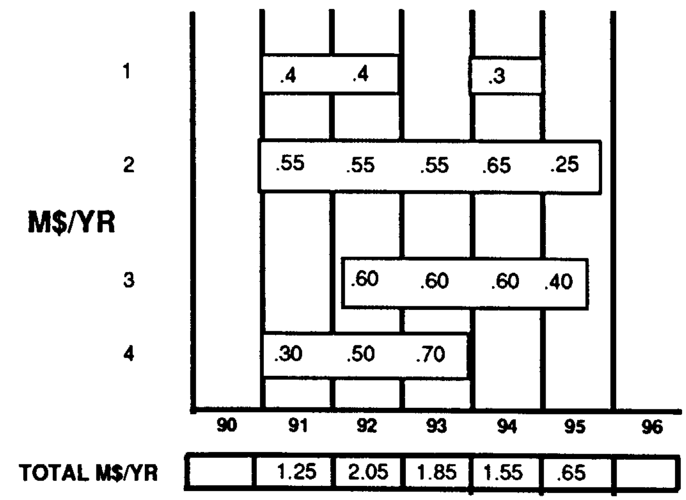
1. Array system architecture/design.
2. Radiator/subarray/ beam-former technology.
3. Surface distortion compensation technique (RF).
4. Antenna testing technique.



TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



LARGE SPACE ANTENNA END-TO-END THERMAL/MECHANICAL/ELECTROMAGNETIC COMPUTER MODELS FOR LARGE RADIOMETER ANTENNA SYSTEMS

SCOPE To develop efficient electromagnetic and computational techniques for large radiometer system end-to-end computer models. This effort will include quasi-optical antenna configurations.

OBJECTIVES

- Multiple reflector system
- Develop end-to-end thermal distortion models
- Accurate performance prediction
- Fast computing time

RATIONALE

Existing analytical and computational techniques using physical optics are too time consuming even using super computers, such as CRAY. Therefore improved computer models are required for future large radiometer systems.

APPROACH

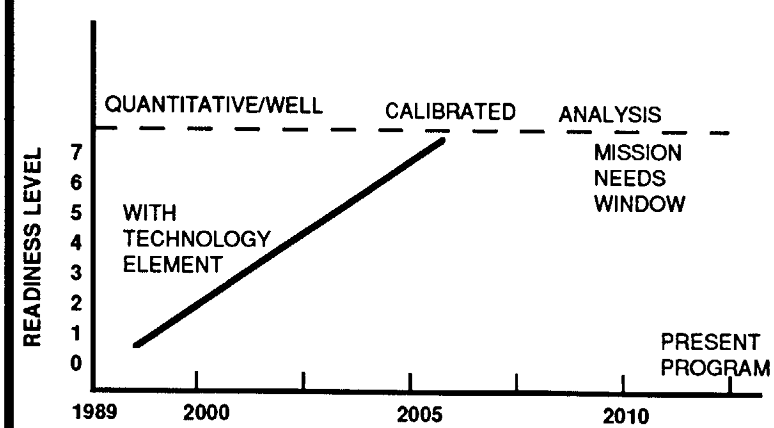
Develop new analytical approach and adapt parallel processing techniques to expedite calculations.

1) New analytical techniques

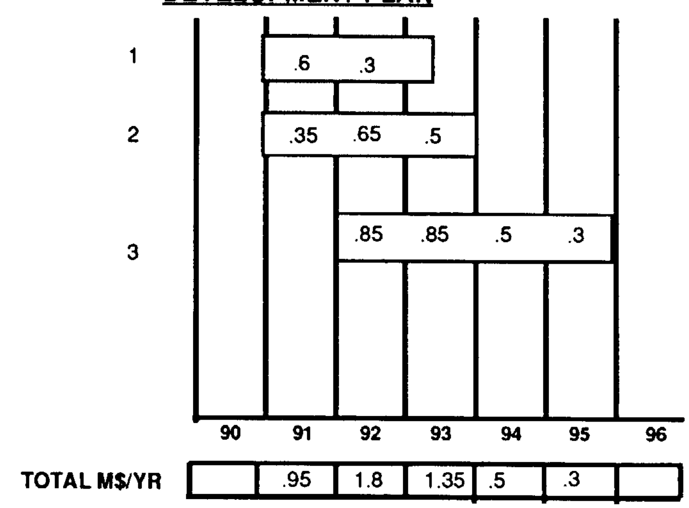
2) Fast computational techniques

3) Experimental verification of analysis and computational technique

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



T. CAMPBELL

MEASUREMENT/CALIBRATION - LARGE SPACE ANTENNAS GROUND TEST METHODOLOGY

SCOPE Develop methodology for ground testing, characterization, and performance verification of large space antennas (LSA) for microwave remote sensing systems.

OBJECTIVES

Develop millimeter wavelength near field (MMW-NF) measurement techniques for measuring wide-scanning, large aperture, low side lobe antenna systems.

RATIONALE

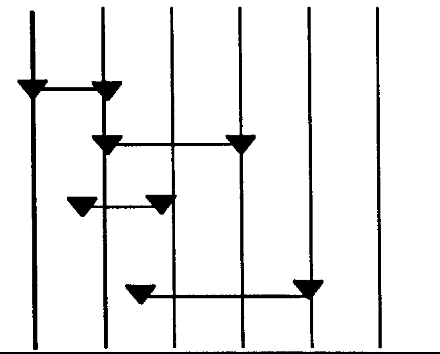
Performance verification of high beam efficiency, wide-scanning antennas critical to microwave remote sensing systems, both passive and active.

APPROACH

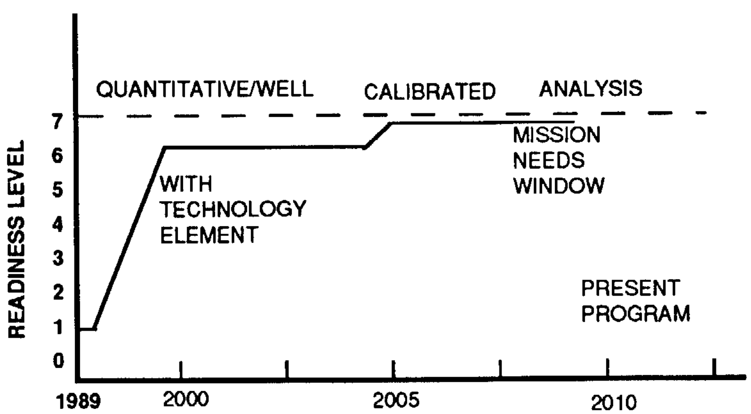
Investigate feasibility of upgrading near-field test laboratory at Martin Marietta-Denver, Colorado (Largest NF-facility in USA) for millimeter wavelengths (~ 100 GHz) and provide advocacy for laboratory upgrade. Develop methodology for determining functional characteristics of integrated sensor/LSA system.

DELIVERABLES

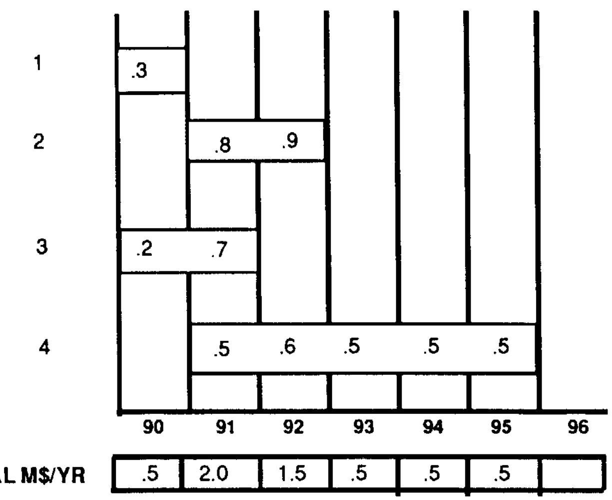
1) MMW-NF Design
2) NF Development
3) LSA- Sensor Measurement Concept
4) Integrated Measurement System



TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



T .CAMPBELL

ELECTRONICALLY SCANNING FEED TECHNIQUES FOR FILLED APERTURE MICROWAVE RADIOMETER

SCOPE

Space-qualified microwave/millimeter wave radiometers which are small, lightweight, low-loss and reliable are required for application in observation of Earth geophysical and atmospheric parameters. Develop electronically scanned phasing networks for precision radiometer applications and study these array techniques for rapid wide angle scanning.

OBJECTIVES

- Develop monolithic microwave integrated circuit (MMIC) front-end radiometer subsystem technology to support GHz radiometer development for space application.
- Reduce effects of varying parameters of combiner networks due to scanning and changes in temperature and loss/mismatch.

RATIONALE

- Earth observation radiometer systems will be used in multiple numbers as part of large space antenna feed systems. Therefore, they must be small, lightweight, and efficient to reduce antenna shadowing and excessive power consumption.
- Electronic scanning likely will be required to obtain desired large coverage for large apertures.

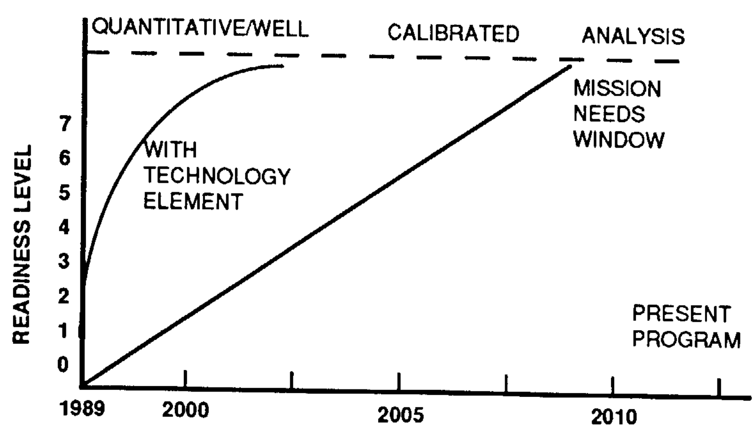
APPROACH

Study techniques to integrate portions of the radiometer system or feed networks to improve radiometer performance. Model effects of variations due to phase shifters on radiometer performance. Develop integrated radiometer front-end, phase shifters, combiners, etc., specifically for radiometer applications. Determine possibility of superconductor application. Study a large array for soil monitor mapping.

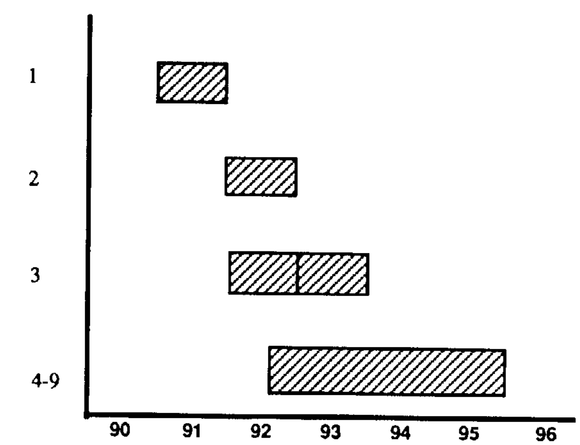
DELIVERABLES

(1) System performance trade-off reports.
(2) Design study reports.
(3) Computer-aided design software.
(4) Demonstrate 60 GHz unit.
(5) Test and validate report.
(6) 118 GHz MMIC low-noise amplifier.
(7) 220 GHz MMIC low-noise amplifier.
(8) Prototype radiometer front-end phasing network. Low frequency parameters.
(9) Identify technology question for higher frequency applications.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



TOTAL M$/YR		.9	2.0	2.8	2.5	2.0	

T. CAMPBELL

CHARACTERIZATION OF REFLECTOR MATERIALS FOR RADIOMETER APPLICATIONS

SCOPE

The performance of radiometer systems employing mesh antenna systems is strongly dependent on material properties of the mesh and detailed radiometric properties of the mesh and mesh structure.

OBJECTIVES

Characterize the radiometric performance and long-term stability of mesh antenna system for 1 - 37 GHz, and determine the impact on overall radiometer system performance.

RATIONALE

Mesh antenna systems are under consideration for radiometer application for 1 - 37 GHz. To determine overall radiometric system performance, it is essential to completely characterize the effects of the mesh.

APPROACH

Using existing radiometric mesh measurement systems and developing new measurement systems and test procedures, characterize the radiometric properties of typical mesh material.

Using these results, model the effect of mesh antenna on overall radiometer system performance.

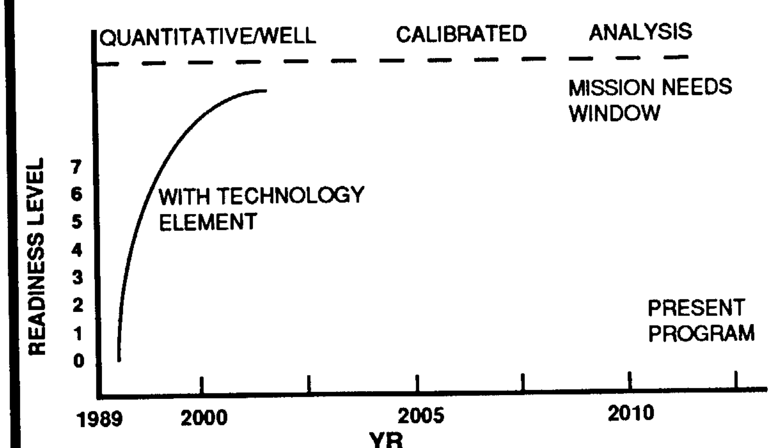
Identify techniques to minimize adverse effects of mesh performance or changes in performance (aging) on overall radiometer system performance.

DELIVERABLES

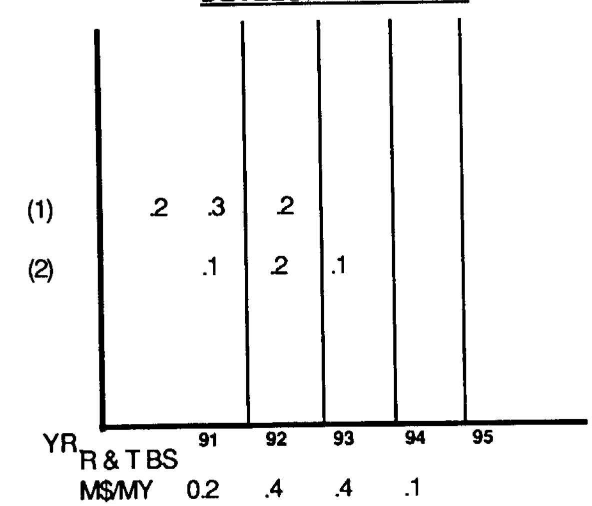
(1) Radiometric mesh measurement system.

(2) Study report modeling effects of mesh antenna on radiometer system performance and indicating improvements possible.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



RADIO FREQUENCY INTERFERENCE (RFI) REJECTION TECHNOLOGY FOR RADIOMETER APPLICATIONS

SCOPE

- Enable use of radiometers near population centers and coastal regions.
- Establish feasibility and produce RFI rejection instrument.

OBJECTIVES

- Radiometry close to populated regions is important to Earth sciences.
- Provide capability of rejecting radio frequency interference over broad band data acquisition and communications channels.

RATIONALE

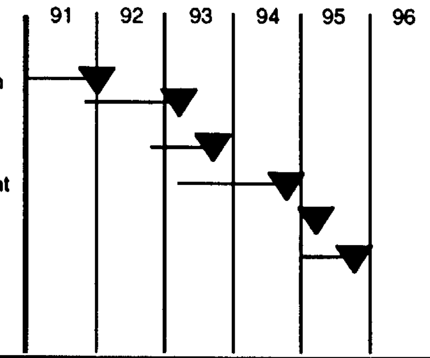
Present observation and communication channels polluted by RFI. Active countermeasures needed to insure integrity of acquired data and fidelity of communication channels.

APPROACH

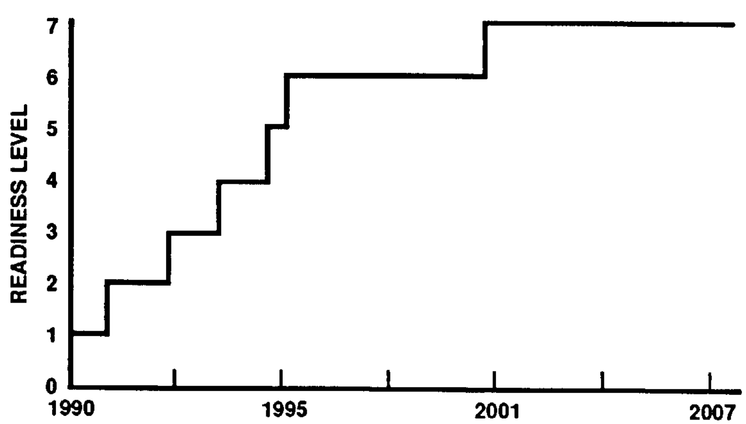
Evaluate use of multichannel spectrum analyzer technology to match filter RFI signal in real time, and excise the RFI from broadband channels of up to several hundred megahertz bandwidth.

DELIVERABLES

(1) Technology evaluation
(2) Conceptual design
(3) Engineering development plan
(4) Prototype development
(5) Laboratory system demonstration
(6) Space demonstration

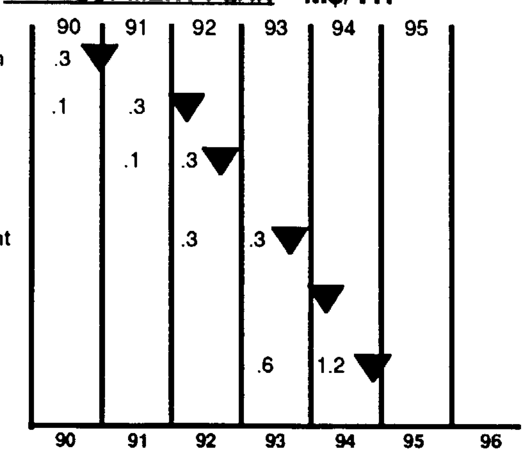


TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN M$/YR

(1) Technology evaluation
(2) Conceptual design
(3) Engineering development plan
(4) Prototype development
(5) Laboratory system demonstration
(6) Space demonstration



TOTAL M$/YR	90	91	92	93	94	95	96
	0.4	0.4	0.6	0.9	1.2		

E. MADARAS

Precision Ranging Radar

SCOPE
DEVELOP A PULSED PHASE LOCK LOOP SYSTEM FOR RADAR RANGING OF CLOUD TOPS FROM SATELLITES.

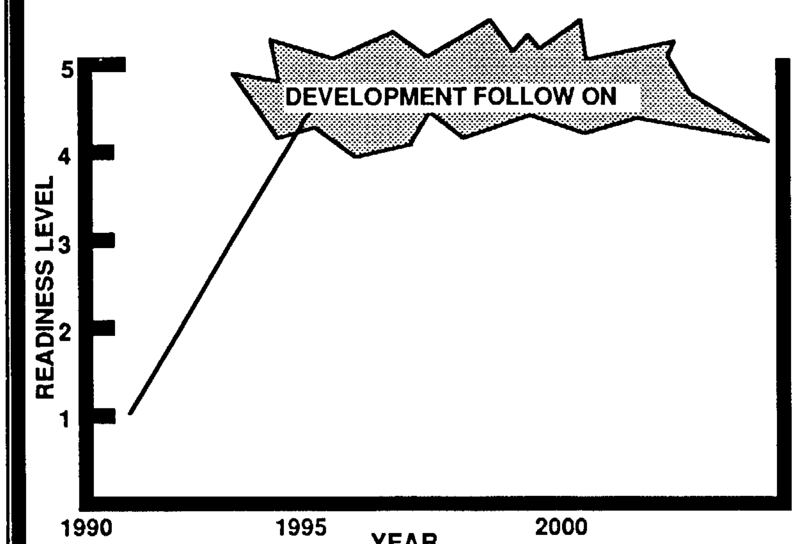
OBJECTIVE
- IMPROVE RADAR RANGING METHODS FROM DIFFICULT REFLECTION SYSTEMS.

RATIONALE
- SOME RADAR REFLECTION SYSTEMS HAVE TROUBLE RANGING TO CLOUD TOPS THAT ARE POOR REFLECTORS.
- A PHASE SENSITIVE MEASUREMENT SYSTEM THAT IS LESS DEPENDENT ON AMPLITUDE VARIATIONS CAN BE MORE SENSITIVE.
- WE HAVE SUCCESSFULLY DEMONSTRATED THIS TECHNOLOGY FOR OPTICAL, ELECTROMAGNETIC, AND ULTRASONIC APPLICATIONS.

APPROACH
- CONSTRUCT A RADAR FREQUENCY PULSE PHASE LOCK LOOP SYSTEM.
- EVALUATE THE SYSTEM FROM A GROUND-BASED SYSTEM.

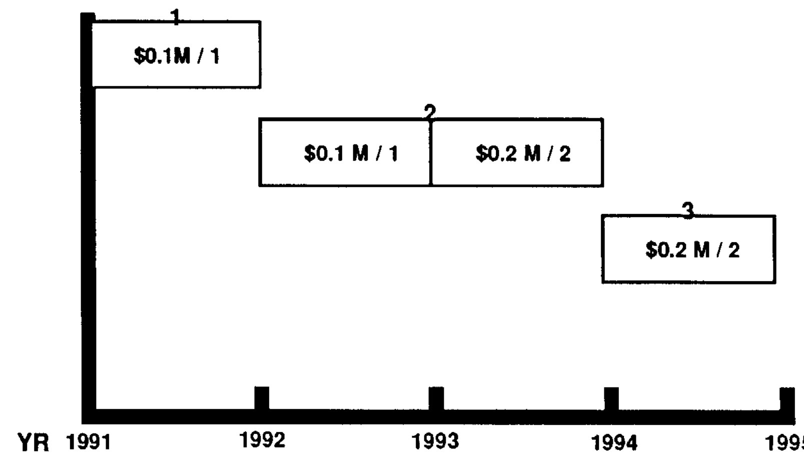
DELIVERABLES
1. DEVELOPMENT OF TECHNOLOGY FOR RADAR SYSTEM.
2. DEVELOPMENT OF RADAR PULSED PHASE LOCK LOOP LAB SYSTEM.
3. EVALUATION OF SYSTEM.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



$/MY				
	$0.1 M	$0.1 M	$0.2 M	$0.2 M
	1	1	2	2

LaRC GCTI Observation Technologies

1.5 Optics

Technology	NASA GCTI WBS	Proposal funding requirements, millions of dollars					
		FY90	FY91	FY92	FY93	FY94	FY95
Radiation tolerant materials	1.51	0.2	0.3	0.6	0.5	0.4	0.1
Contamination	1.51	0.2	0.25	0.3	0.2	0.1	
Cryogenic materials	1.51	0.1	0.15	0.55	0.75	0.25	
Optics/thermal/control/structure interaction	1.52		0.15	0.3	0.4	0.25	
Unwanted radiation	1.52	0.2	0.4	0.5	0.5	0.2	0.2
Lightweight optics	1.53		0.75	1.0	3.0	2.5	
Ultrastable optical mounts	1.53		0.25	0.35	0.45	0.40	0.30
Microlens technology	1.53	0.15	0.3	0.4	0.5	0.1	
Active cavity radiometer		0.125	0.125	0.2	0.2	0.5	0.5
Totals		0.975	2.675	4.2	6.5	4.70	1.10

RADIATION TOLERANT MATERIALS

L. KOPIA

SCOPE

DEVELOP HIGHLY REFLECTIVE, BROAD SPECTRAL BAND DIELECTRIC OPTICAL COATINGS WHICH ARE HIGHLY RESISTANT TO ELECTROMAGNETIC AND PARTICLE RADIATION.

OBJECTIVE

DEVELOP OPTICAL COATINGS THAT CAN BE USED FOR LONG DURATION SPACE APPLICATIONS. THESE COATINGS WILL BE USED ON INTERNAL ELEMENTS OF HIGH ENERGY LASER SYSTEMS AND ON OPTICAL ELEMENTS EXPOSED TO SPACE RADIATION, INCLUDING SOLAR ULTRAVIOLET.

RATIONALE

PRESENT OPTICAL COATINGS SUFFER FROM RADIATION DAMAGE IN HIGH ENERGY LASER SYSTEMS RESULTING IN DEGRADED PERFORMANCE AND DAMAGE TO SUBSTRATE MATERIALS. LONG-TERM MISSIONS REQUIRE HIGH INTEGRITY OPTICAL SYSTEMS WHOSE FRONT END ELEMENTS ARE NOT DEGRADED WHEN EXPOSED TO CONTINUOUS HIGH ENERGY PARTICLE AND UV BOMBARDMENT.

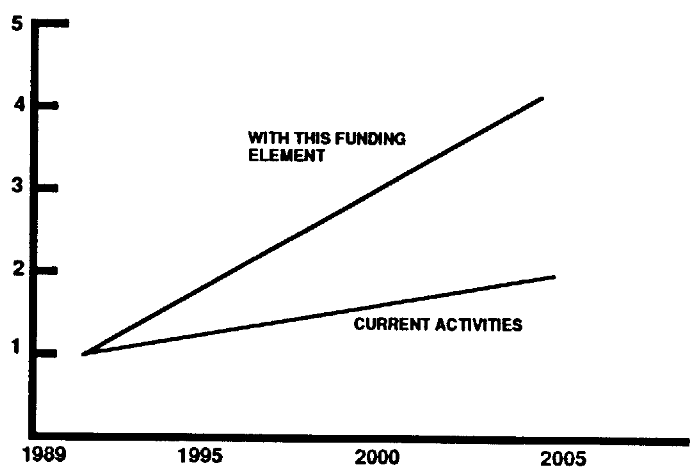
APPROACH

EXAMINE METHODS AND MATERIALS OF DEPOSITING COATINGS, E.G., DIAMOND-LIKE MATERIALS, WHICH DEMONSTRATE HIGH RADIATION RESISTANCE. DEVELOP MATERIAL COMBINATIONS WHICH PERMIT BROADENING SPECTRAL RANGE. ESTABLISH EXPERIMENTAL PROGRAM TO DEFINE RADIATION DAMAGE PROPERTIES.

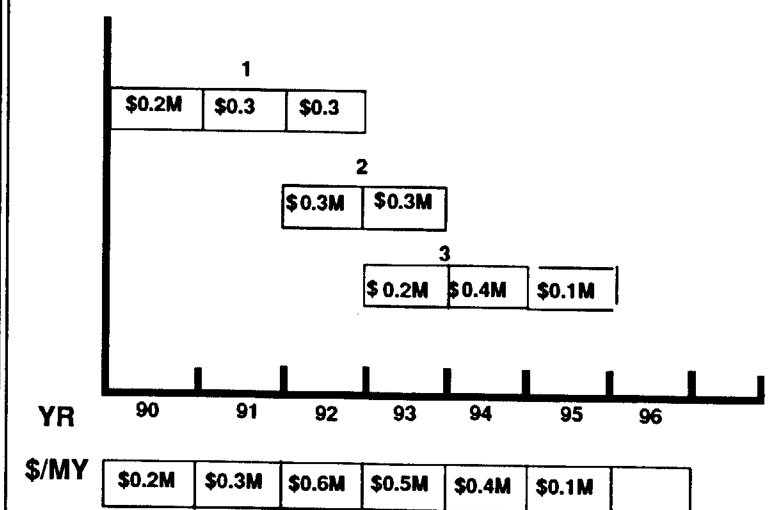
DELIVERABLES

1. DEVELOP COATING MATERIAL AND COATING PROCESSES WHICH SURVIVE MULTIGIGAWATT INCIDENT RADIATION IN THE UV AND NEAR-UV SPECTRAL RANGE.
2. DEMONSTRATE APPLICABILITY OF COATINGS TO BROAD SPECTRAL BAND COVERAGE.
3. DEMONSTRATE PERFORMANCE OF THESE COATINGS FOR SPACE-BASED LASER AND OPTICAL COMPONENT USE.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



CONTAMINATION

J. GOAD

SCOPE

OPTICAL SYSTEMS EXHIBIT PERFORMANCE DEGRADATION WHEN CONTAMINANTS ARE DEPOSITED ON SURFACES. METHODS ARE NEEDED TO DEFINE OPTICAL PERFORMANCE DEGRADATION IN TERMS OF DEFINED CONTAMINATION LEVELS.

OBJECTIVE

THE OBJECTIVES OF THIS PROGRAM ARE TO MODEL, DEVELOP, TEST, AND INTEGRATE ANALYSIS AND EXPERIMENTAL TECHNIQUES TO EVALUATE IMAGE AND/OR OPTICAL PERFORMANCE DEGRADATION FROM CONTAMINATION.

RATIONALE

HIGHER RESOLUTION DATA FROM INFRARED DETECTION SYSTEMS AND THE REQUIREMENTS OF COHERENT DETECTION OF LASER SIGNALS, AS IN LIDAR, OR IN SCANNING LIDAR, DEMAND BETTER PERFORMANCE FROM THE GEOMETRIC SYSTEM THAT COMPRISES THE OPTICS. THIS WORK IS REQUIRED TO IMPROVE THEIR DESIGN EASE, ANALYSIS, PERFORMANCE, AND LIFETIMES. UNDERSTANDING OF PERFORMANCE DEGRADATION AND LIFETIMES DUE TO CONTAMINATION SIGNIFICANTLY IMPROVES THE PREDICTABILITY OF OPTICAL SYSTEMS PERFORMANCE.

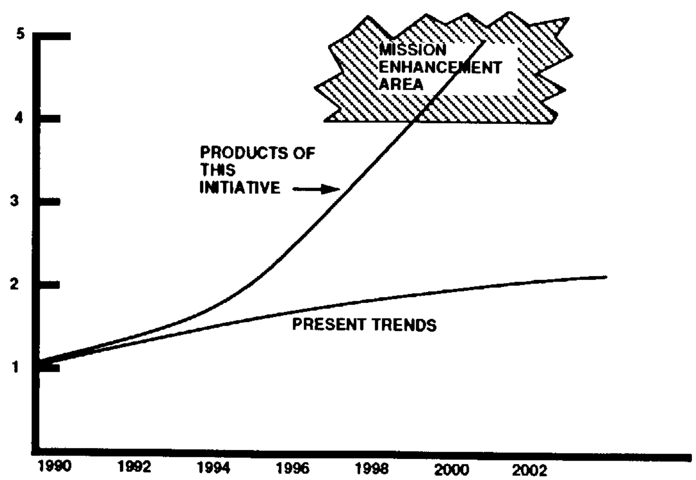
APPROACH

A PUBLICATION AND INDUSTRIAL SURVEY WILL BE CONDUCTED TO COMPARE THE ADVANTAGES AND DISADVANTAGES OF AVAILABLE METHODS. ONCE DEFINED, A TWO-LEVEL ANALYSIS WILL BE DEVELOPED TO ASSESS PERFORMANCE. THIS ANALYSIS WILL BE VERIFIED BY EXPERIMENT. NEW NONCONTACT CLEANING METHODS WILL BE DEVELOPED.

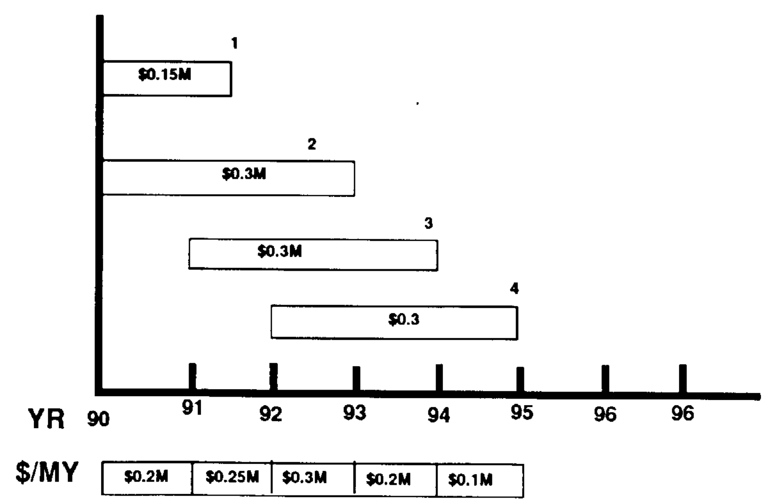
DELIVERABLES

1. MATERIALS RESOURCE CATALOG.
2. TWO-LEVEL ANALYSIS.
3. EXPERIMENTAL RESULTS.
4. DEVELOPMENT OF CLEANING AND/OR CORRECTION TECHNIQUES.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



LaRC

J. GOAD

CRYOGENIC OPTICAL MATERIALS

SCOPE

OPTICAL SYSTEMS OPERATING IN CRYOGENIC ENVIRONMENTS REQUIRE STABLE OPTICAL MATERIALS. THIS WILL INCLUDE THE DEVELOPMENT OF SPECIAL MATERIALS AND MANUFACTURING PROCESSES.

OBJECTIVE

THE OBJECTIVES OF THIS PROGRAM ARE TO PROVIDE A BASELINE SET OF PRODUCTS THAT WILL SUPPLY THE BROAD NEEDS OF THE OPTICAL SYSTEMS OF THE 1994 ERA. FROM THIS BASELINE SET OF MATERIALS, OPTICAL SYSTEMS, AND MANUFACTURING PROCESSES, NEW CRYOGENIC OPTICAL INSTRUMENTATION SYSTEMS WILL BE DEVELOPED.

RATIONALE

HIGHER RESOLUTION DATA FROM INFRARED DETECTION SYSTEMS AND THE REQUIREMENTS OF COHERENT DETECTION OF LASER SIGNALS, AS IN LIDAR, OR IN SCANNING LIDAR, DEMAND BETTER PERFORMANCE FROM THE GEOMETRIC SYSTEM THAT COMPRISES THE OPTICS. THIS WORK IS REQUIRED TO IMPROVE THEIR DESIGN EASE, ANALYSIS, PERFORMANCE, AND LIFETIMES.

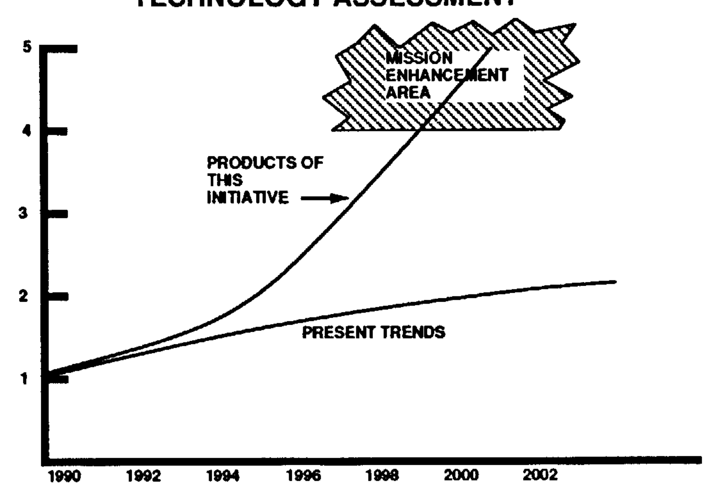
APPROACH

DEVELOP A MATERIALS RESOURCE CATALOG FOR CRYOGENIC OPTICAL MATERIALS. THIS CATALOG WILL BE REVIEWED TO ESTABLISH THE REQUIREMENTS FOR NEW MATERIALS. DEVELOPMENT OF NEW MATERIALS WILL BE INITIATED AND A TEST PROGRAM COMPLETED.

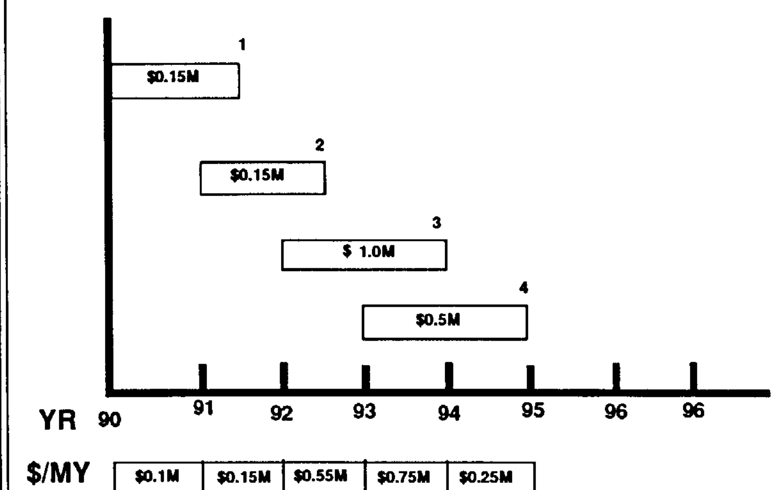
DELIVERABLES

1. MATERIALS RESOURCE CATALOG.
2. REQUIREMENTS FOR NEW MATERIALS.
3 DEVELOP NEW MATERIALS.
4. TEST PROPERTIES OF NEW MATERIALS.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



LaRC

R. BAKER

OPTICS-THERMAL-CONTROL-STRUCTURES INTERACTION

SCOPE
Develop integrated thermal-structural-control-optical analysis capability for space instrument applications.

OBJECTIVE
Develop an integrated analysis tool for evaluating optical system performance with thermal and structural disturbances (including adaptive systems).

RATIONALE
- With increased optical beam stability requirements, a tool is necessary to assure performance over representative thermal and dynamic environments.
- Tools required to efficiently evaluate and integrate the design of precision optical systems as well as entire optical experiments. With long-life missions (active cooling), larger flexible platforms (structural coupling), and higher orbits (better stability), analysis tools are required to evaluate disturbance effects.
- Analysis tools are needed to evaluate the optical system performance with adaptive optical elements.

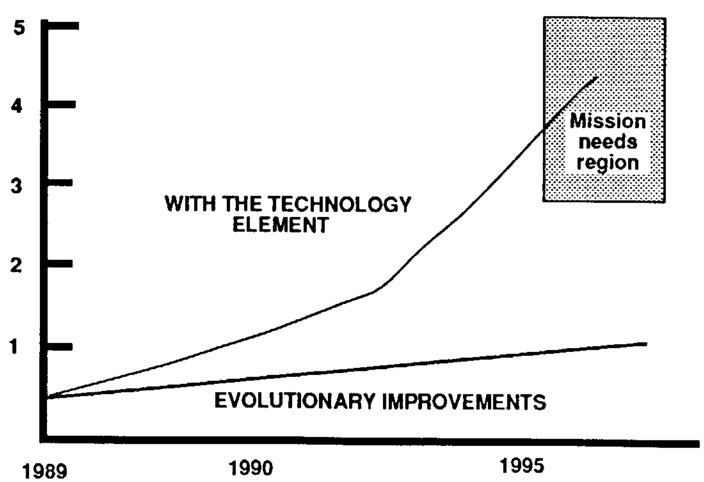
APPROACH
Review existing candidate analysis codes in each discipline and select the most compatible.

Develop the selected codes into an integrated tool and demonstrate its capability.

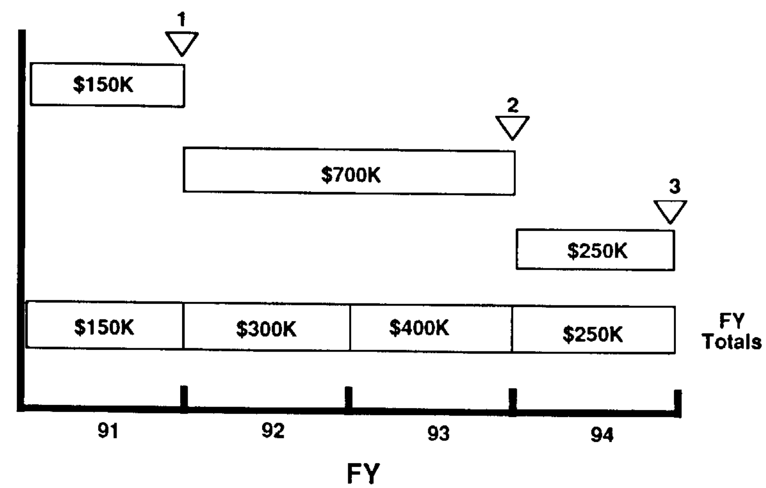
Provide technology to industry to market.

DELIVERABLES/MILESTONES
1. Selection of compatible codes.
2. Development of interfaces and data bases necessary to integrate codes.
3. Demonstration of integrated analysis capability.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



L. KOPIA

UNWANTED RADIATION (SCATTERED THERMAL)

SCOPE

DEVELOP MODELING AND DESIGN PROCESSES TO PREDICT THERMAL INFRARED SYSTEM PERFORMANCE

OBJECTIVE

CREATE AN ANALYTICAL TOOL FOR THE OPTICAL DESIGN AND OPTIMIZATION OF THERMAL INFRARED SYSTEMS FOR REMOTE SENSING SYSTEMS IN THE INFRARED (IR) REGION OF THE SPECTRUM. MODEL THERMAL IR BACKGROUND SIGNAL, ATMOSPHERIC TRANSMISSION, AND PROPAGATION THROUGH THE OPTICAL SYSTEM.

RATIONALE

THERMAL IMAGING IS USED FOR MEASURING GLOBAL WARMING TRENDS, GREENHOUSE GASES, AND EVAPOTRANSPIRATION. THERMAL BACKGROUND CHARACTERISTICS BECOME MORE CRITICAL WITH INCREASING INTEREST TOWARD USING IR MATERIALS AT HIGHER OPERATING TEMPERATURES. THESE IMPROVEMENTS YIELD BETTER INFORMATION ON THE OPTIMUM PERFORMANCE, SENSITIVITY, DURABILITY, AND UNIFORMITY OF OPTICAL MATERIAL AND DETECTOR ARRAYS. THIS WORK PROVIDES SIGNIFICANT NEW SCIENTIFIC INFORMATION IN THE THERMAL IR AT LOWER DETECTABLE LEVELS AND BETTER PRECISION.

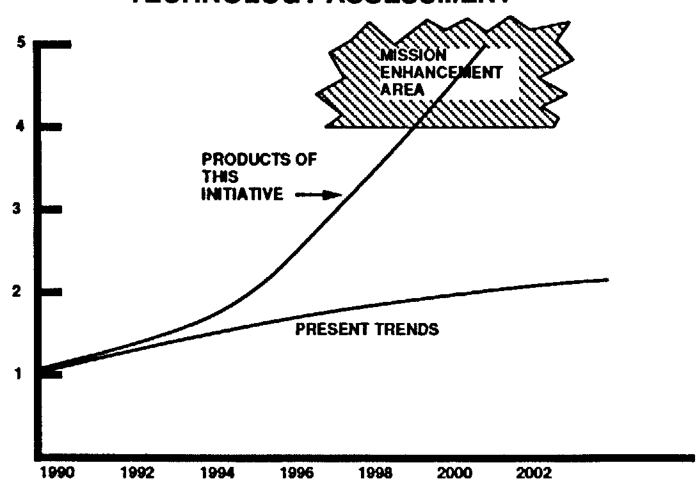
APPROACH

DEVELOP COMPUTER-AIDED DESIGN (CAD) SOFTWARE FOR THE ANALYSIS AND OPTIMIZATION OF THERMAL INFRARED SYSTEMS. ADEQUATELY MODEL THERMAL CHARACTERISTICS WITHIN THE SENSOR AND QUANTIFY NOISE TERMS FROM EACH COMPONENT. USE THE DEVELOPED MODEL AS A DESIGN AND ANALYSIS TOOL TO SIMULATE SYSTEM CHARACTERISTICS. QUANTIFY SYSTEM BACKGROUND NOISE AS A FUNCTION OF TEMPERATURE. PERFORM LABORATORY MEASUREMENTS TO VERIFY THE ACCURACY OF THE SOFTWARE.

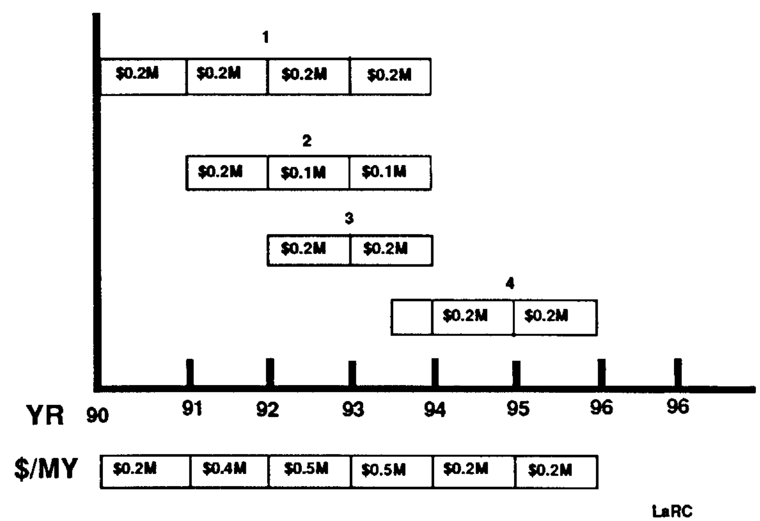
DELIVERABLES

1. DEVELOP CAD ANALYSIS FOR THERMAL IR SYSTEMS.
2. MODEL SENSORS AND QUANTIFY NOISE TERMS.
3. MODEL SYSTEM CHARACTERISTICS.
4. PERFORM LABORATORY MEASUREMENTS TO VERIFY MODEL PREDICTIONS.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



L. KOPIA

LIGHTWEIGHT OPTICS

SCOPE

Develop and demonstrate technology for lightweight and low cost optical systems for spaceflight instrument systems.

OBJECTIVES

Enable large precision optical systems for spaceflight lidar and infrared systems, including the expanded use of scanning and pointing systems for large systems.

RATIONALE

Many instrument concepts are seriously constrained by the mass and cost of large-scale optical systems.

The performance and operational capabilities of lidar systems are seriously constrained by the mass and cost of current optical technology for return-signal systems.

DOD research and technology programs are rapidly evolving materials and manufacturing technologies for lightweight optical systems.

APPROACH

Maintain NASA funding of selected technology efforts.

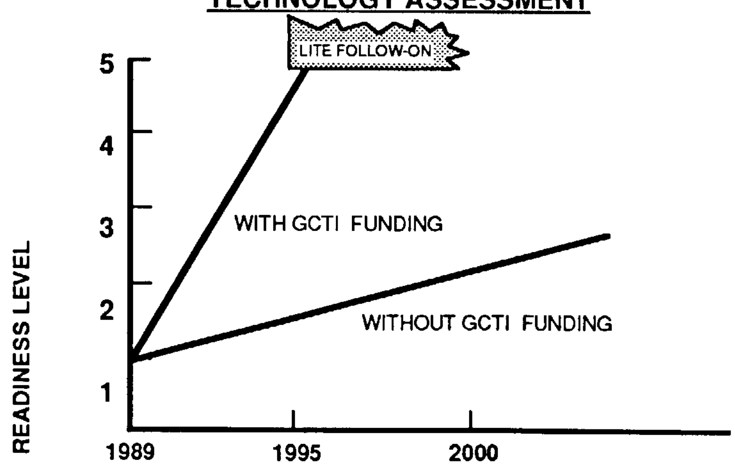
Develop a concept for an initial target application, potentially lidar in-space technology experiment (LITE).

Develop and conduct test bed demonstration of lightweight optical system on laser atmospheric sounding experiment (LASE) or LITE.

DELIVERABLES

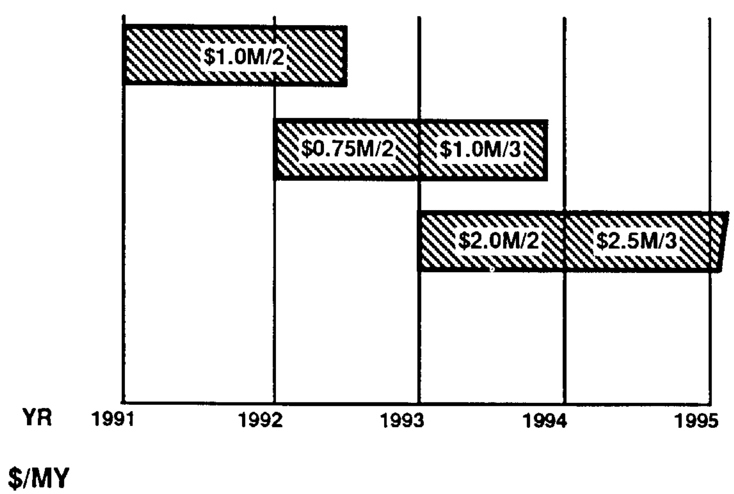
1. Evaluation of candidate technologies under lidar and infrared operating conditions.
2. Development of design for test bed application.
3. Development, test, and application of test bed system (optical system development cost only).

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



R. BAKER

ULTRASTABLE OPTICAL MOUNTS AND BENCH

SCOPE

Develop ultrastable optical bench and mounts for space applications.

OBJECTIVES

Develop lightweight optical mount and bench for application to remote sensing instruments.

Maintenance of optical beam stability under representative thermal and dynamic environments.

RATIONALE

Future missions need ultrastable optical systems for achieving measurement accuracy and spatial and temporal resolution. Development of thermally stable and vibration-resistant mounts and benches will permit accommodation of long-life missions that have inherent disturbance sources.

APPROACH

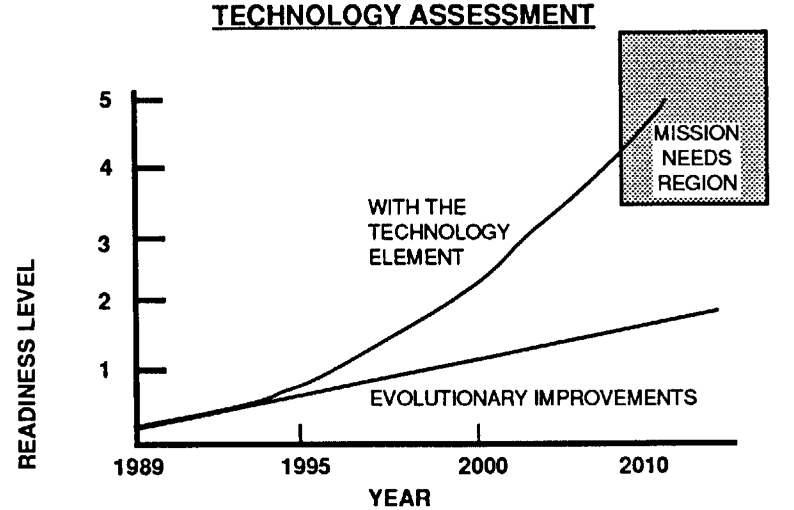
Review candidate advanced materials and structural concepts.

Develop the most promising concepts and demonstrate hardware performance under simulated space environments.

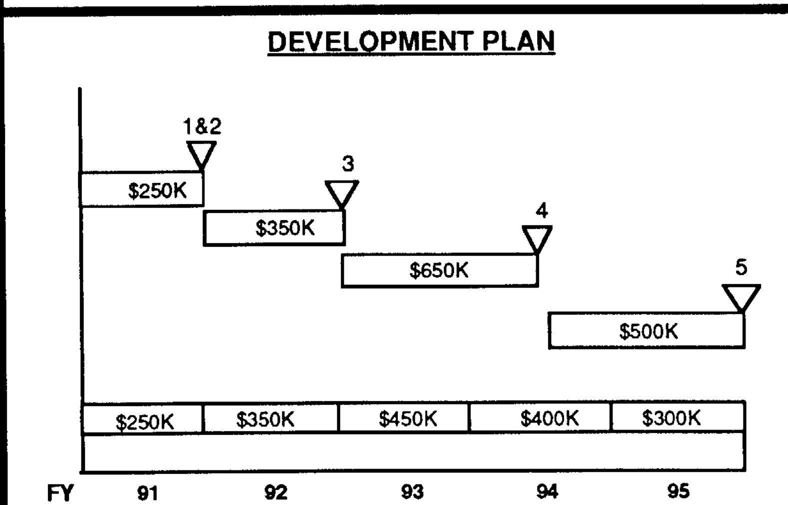
DELIVERABLES/MILESTONES

1. Select candidate materials and identify candidate design concepts.
2. Select most promising concept.
3. Complete detailed design of concept.
4. Complete fabrication of concept hardware.
5. Demonstrate stability in thermal/vacuum environment.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



L. KOPIA

ADVANCED SENSOR CONCEPTS--MICROLENS TECHNOLOGY FOR PUMPING SOLID-STATE LASERS

SCOPE

DEVELOP MICROLENS TECHNOLOGY TO PROVIDE EFFICIENT OPTICAL MATCHING AND IMPROVED COOLING OF LASER DIODES USED TO PUMP SOLID-STATE LASER MATERIALS.

OBJECTIVE

TO PUMP SOLID-STATE LASER MATERIALS, LASER DIODE PUMPING CAN PROVIDE LONG LIFETIMES AND HIGH EFFICIENCY TUNABLE LASERS NEEDED FOR SPACECRAFT APPLICATIONS.

RATIONALE

PROPER OPTICAL MATCHING WITH MICROLENS TECHNOLOGY WILL PROVIDE MORE EFFICIENT PUMP COOLING FOR SOLID-STATE MATERIALS AND ALLOW MORE EFFICIENT COOLING OF THE LASER DIODE PUMPS.

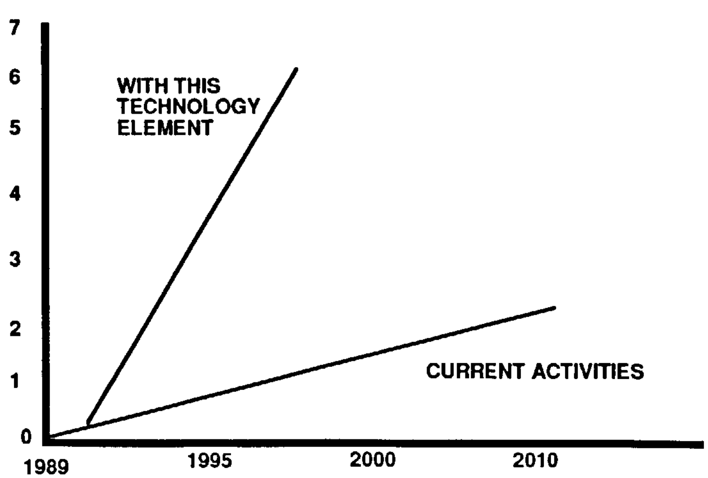
APPROACH

OPTICAL DESIGN PROGRAMS AND THERMAL COOLING MODELS WILL BE USED TO PREDICT THE BEST DESIGNS. THESE DESIGNS WILL BE BREADBOARDED FOR MODEL VALIDATION. ONCE VALIDATED, A PROTOTYPE LASER SYSTEM WILL BE DEVELOPED.

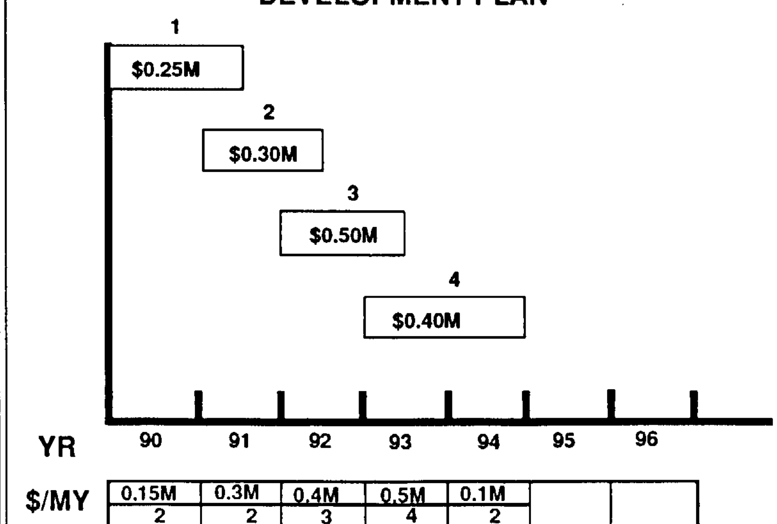
DELIVERABLES

1. OPTICAL DESIGN AND THERMAL MODELING
2. BREADBOARD DESIGN
3. BREADBOARD LABORATORY VALIDATION
4. PROTOTYPE TECHNOLOGY DEMONSTRATION

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



L. KOPIA

ADVANCED SENSOR CONCEPTS--CRYOGENIC ACTIVE CAVITY RADIOMETER TECHNOLOGY

SCOPE

DEVELOP A HIGH-SENSITIVITY, NARROW-FIELD-OF-VIEW ABSOLUTE RADIOMETER CAPABLE OF BEING USED AS EARTH RADIANCE SENSOR.

OBJECTIVE

PRODUCE HIGHLY ACCURATE, LOW RESOLUTION RADIANCE IMAGERY OF THE EMITTED AND REFLECTED RADIATION FROM THE EARTH FOR CLIMATE STUDIES AND GLOBAL CIRCULATION APPLICATIONS.

RATIONALE

PRESENT ABSOLUTE RADIOMETRY INVOLVES THE USE OF ACTIVE CAVITY RADIOMETERS HAVING LONG RESPONSE TIME AND LOW SENSITIVITY. THE USE OF A DEVICE OF THIS TYPE FOR NARROW FIELD, EARTH-VIEWING APPLICATIONS (WHETHER SCANNING OR STARING ARRAY) REQUIRES THAT THE DEVICE(S) BE COOLED TO LIQUID HELIUM TEMPERATURES TO OBTAIN THE REQUISITE OPERATIONAL CHARACTERISTICS.

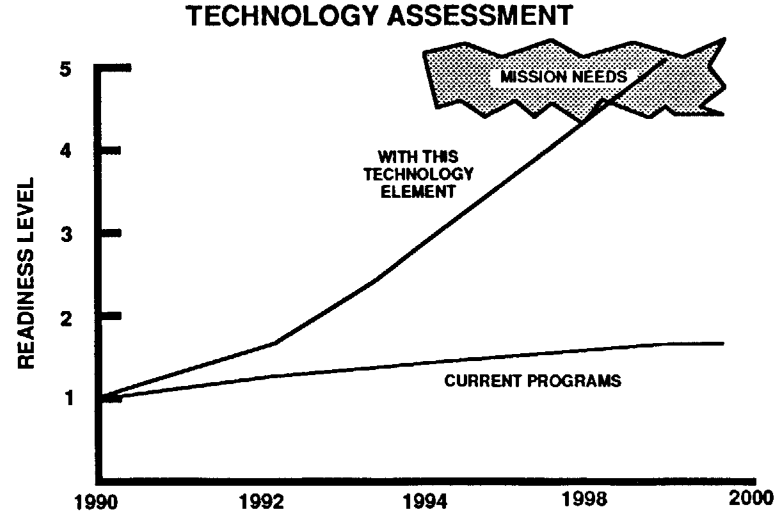
APPROACH

EXPAND PRESENT INVESTIGATIONS TO INCLUDE SCANNING AND/OR ARRAY TECHNIQUES FOR THE PACKAGING OF CRYOGENICALLY COOLED ACTIVE CAVITY RADIOMETER. DETERMINE THE THERMAL, CALIBRATION, AND OPERATIONAL CONSTRAINTS AND INTERFACE RESTRICTIONS FOR SUCH A SYSTEM COMPATIBLE WITH CLIMATE MODELING REQUIREMENTS. REDUCE TIME CONSTANT, INCREASE SENSITIVITY AND THE FIELD OF VIEW, AND IMPROVE IMAGE FORMATS.

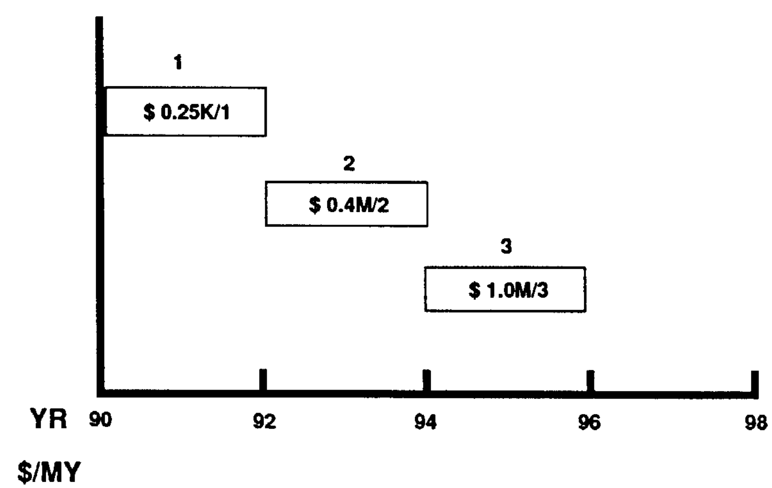
DELIVERABLES

1. PACKAGING REQUIREMENTS OF SENSOR (MULTIELEMENT SENSOR ARRAY VS. SINGLE ELEMENT SCANNING DEVICE)
2. THERMAL AND OPERATIONAL RESTRICTIONS (INCLUDING CALIBRATION) OF CRYOGENICALLY COOLED CAVITY RADIOMETER.
3. PROTOTYPE SYSTEM TO DEMONSTRATE FEASIBILITY.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



LaRC GCTI Observation Technologies

1.6 Pointing and Control

Technology	NASA GCTI WBS	Proposal funding requirements, millions of dollars					
		FY90	FY91	FY92	FY93	FY94	FY95
Advanced pointing/servo	1.61		0.5	0.5	0.5	0.5	0.4
Mechanical scanning			0.2	0.4	2.0	0.7	
Advanced fiber optics			0.2	0.2	0.2	0.3	0.3
Totals			0.9	1.1	2.7	1.5	0.7

R. BAKER

ADVANCED POINTING/SERVO TECHNOLOGY

SCOPE

Explore techniques for advanced pointing/servo technology for instrument pointing.

OBJECTIVE

Develop new pointing control strategies and technologies for high accuracy/high stability servo applications.

RATIONALE

Conventional pointing control sensors (encoders, resolvers, etc.) are at their limits in control of present space instrument pointing. Higher accuracy/stability of future pointing systems will require a new generation of internal position-sensing mechanisms and control strategies. Techniques for isolation and pointing control via high accuracy and high compliance magnetic bearings show great promise, but have had limited attention.

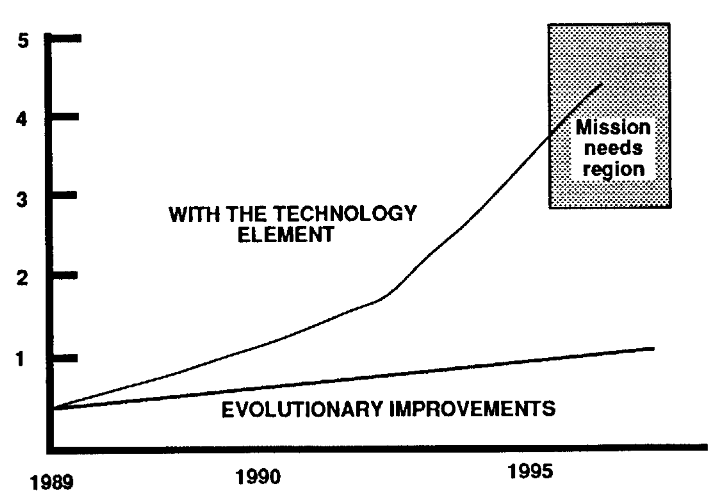
APPROACH

Evaluate pointer/servo requirements for EOS and beyond. Survey manufacturers and scientific literature to identify promising sensor technologies. Develop and model new control strategies and mechanisms to satisfy high accuracy/high stability servo applications. Develop and test proof-of-concept model(s).

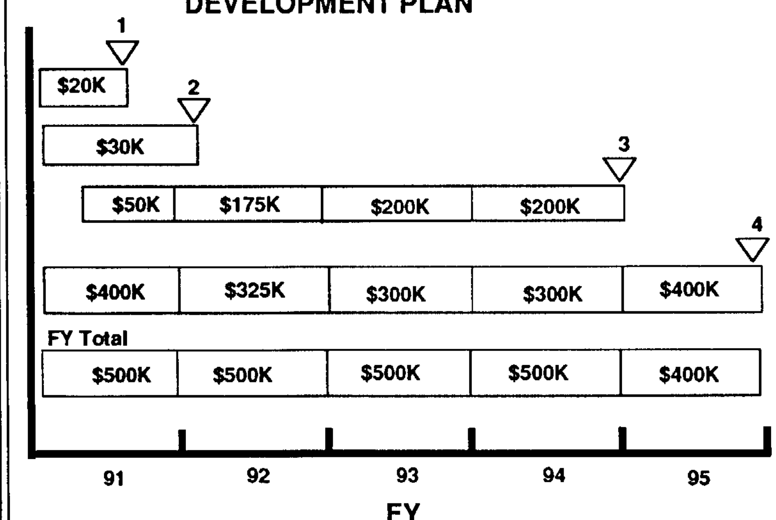
DELIVERABLES/MILESTONES

- Survey EOS and beyond pointing requirements in terms of required gimbal parameters.
- Survey of promising sensor technologies.
- Report "Pointing and Control Using Advanced Strategies and Mechanisms" (excluding magnetic bearings).
- Report "Pointing and Control Using Advanced Strategies and Mechanisms with Magnetic Bearing Technology."

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



R. BAKER

MECHANICAL SCANNING CONCEPTS FOR LARGE OPTICAL SYSTEMS

SCOPE

DEVELOP AND DEMONSTRATE CONCEPTS AND TECHNOLOGIES TO ENABLE SCANNING BY FUTURE INSTRUMENTS WITH LARGE OPTICAL SYSTEMS.

OBJECTIVE

- ENABLE COVERAGE OF THE FULL EARTH DISC WITH HIGH RESOLUTION.
- ENHANCE THE CAPABILITY TO PROVIDE MULTIPLE SATELLITE/ INSTRUMENT COVERAGE OF AREAS OF SCIENTIFIC INTEREST.
- AVOID THE TRADE-OFFS BETWEEN RESOLUTION AND COVERAGE.
- ENHANCE THE POSSIBILITIES OF IDENTIFYING AND STUDYING UNANTICIPATED EVENTS AND/OR PHENOMENA.

RATIONALE

THE SCIENTIFIC RETURN AND VIABILITY OF MANY INSTRUMENT CONCEPTS COULD BE SIGNIFICANTLY ENHANCED BY THE ADDITION OF SCANNING CAPABILITY.

EVOLVING TECHNOLOGIES IN LIGHTWEIGHT, LARGE APERTURE, OPTICAL SYSTEMS ARE BROADENING THE RANGE OF INSTRUMENT SYSTEMS WHERE SCANNING SYSTEMS CAN BE EMPLOYED.

APPROACH

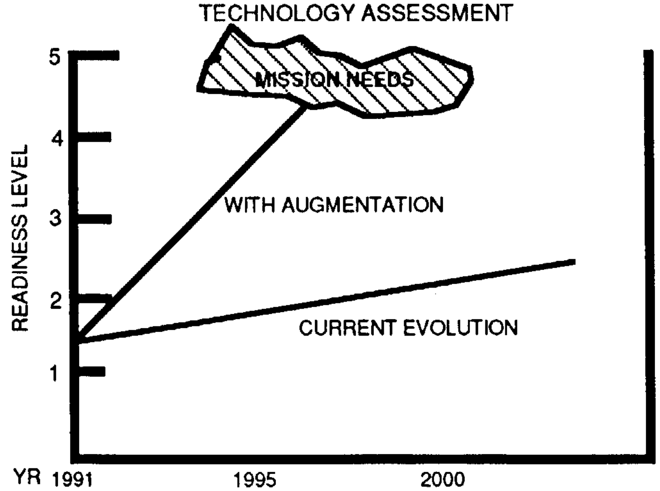
MULTIDISCIPLINE APPROACH WHICH WILL ENCOMPASS SERVO DESIGNS, MECHANICAL SYSTEMS, AND MOMENTUM COMPENSATION SYSTEMS IN THE DEVELOPMENT OF CANDIDATE SCANNING CONCEPTS.

DEVELOP AND DEMONSTRATE A CANDIDATE CONCEPT.

DELIVERABLES

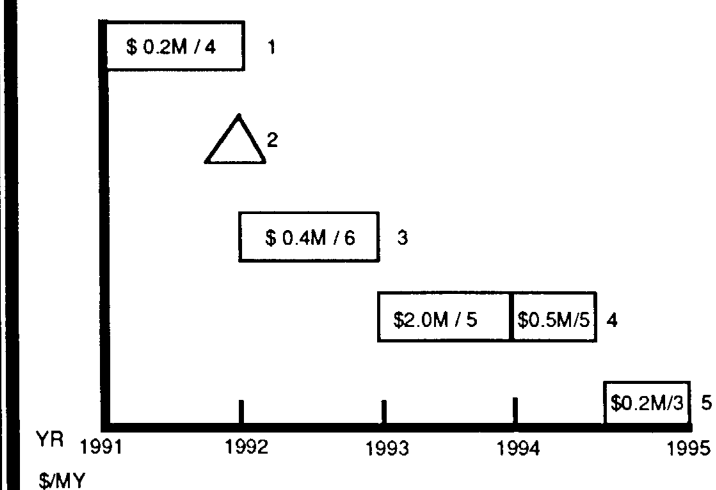
1. DEVELOPMENT OF CANDIDATE CONCEPT(S) WITH TRADE-OFF ANALYSIS.
2. CONCEPT SELECTION.
3. DESIGN DEVELOPMENT.
4. DEVELOPMENT OF FULL-SCALE FUNCTIONAL MODEL.
5. TEST AND EVALUATION.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS 2 THROUGH 5

DEVELOPMENT PLAN



E. MADARAS

Advanced Fiber Optic Sensors for NDE of Critical Structures

SCOPE
DEVELOP AND INTEGRATE FIBER OPTIC SENSORS WITH CRITICAL STRUCTURES FOR ADVANCED NDE NEEDS.

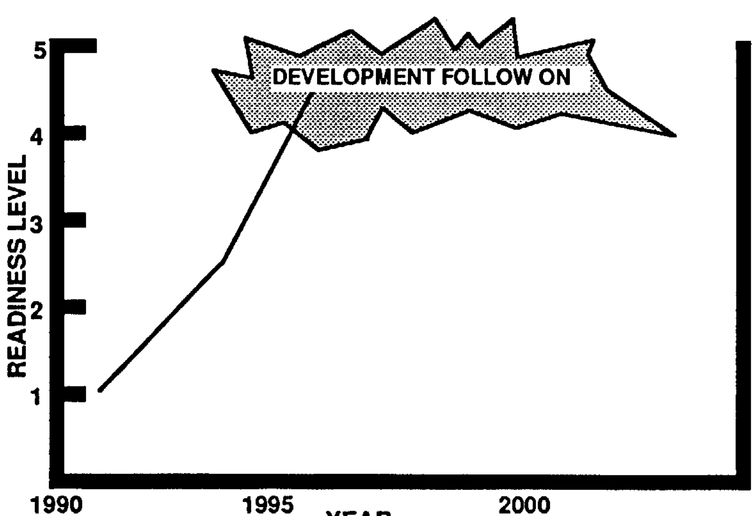
OBJECTIVE
- PROVIDE REAL-TIME INFORMATION ABOUT STRAIN, TEMPERATURE, CONFIGURATION, IMPACT DAMAGE, THERMAL DEGRADATION, AND RADIATION DEGRADATION.

RATIONALE
- PROVIDE A SENSOR FEEDBACK LOOP FOR STRUCTURAL CONFIGURATION OF ANTENNA DISTORTION.
- MONITOR MATERIAL CONDITIONS AND DEGRADATIONS.
- NEED FOR A MODAL FIBER-OPTIC SMART SENSOR FOR DYNAMIC ANALYSIS.

APPROACH
- DEVELOP METHODS FOR INCORPORATING FIBER OPTICS INTO SPACE STRUCTURES.
- DEVELOP THE RELATIONSHIP OF ACOUSTIC EMISSION SIGNALS TO DAMAGE.
- DEVELOP THE RELATIONSHIP BETWEEN THERMAL AND STRAIN BEHAVIOR OF FIBER OPTICS.

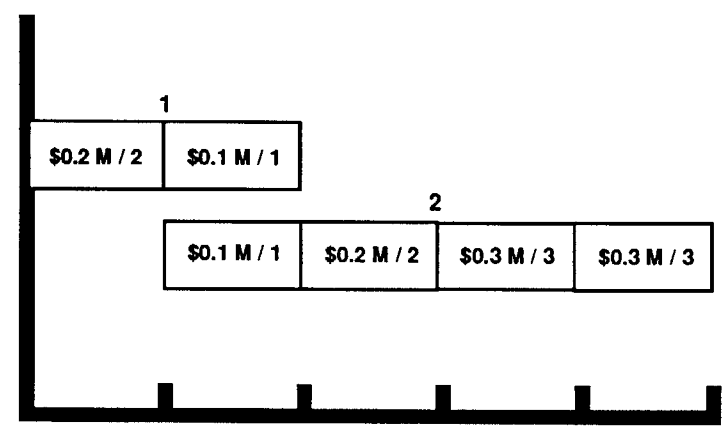
DELIVERABLES
1. DEVELOP THE METHODS FOR INCORPORATING FIBER OPTICS INTO SPACE STRUCTURES.
2. DEVELOP A PROTOTYPE SYSTEM TO VERIFY THE CAPABILITIES OF MEASURING STRAIN, CONFIGURATION, TEMPERATURE, IMPACT DAMAGE, AND DEGRADATION OF A STRUCTURAL SYSTEM.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



YR 1991	1992	1993	1994	1995	1996
$/MY	$0.2 M / 2	$0.2 M / 2	$0.2 M / 2	$0.3 M / 3	$0.3 M / 3

LaRC GCTI Observation Technologies

1.7 Lasers

Technology	NASA GCTI WBS	Proposal funding requirements, millions of dollars					
		FY90	FY91	FY92	FY93	FY94	FY95
Semiconductor laser arrays	1.75		1.0	1.2	1.2	2.0	0
Midinfrared lidar technology	1.71		1.0	1.0	1.5	2.0	0
Coherent doppler lidar	1.72		0.3	0.7	1.3	2.4	4.0
CO_2 laser catalyst	1.72		1.0	1.0	2.0	2.0	2.0
Scanning lidar technology	1.73		0.25	0.5	1.5	1.0	2.0
Laser wavemeter	1.73	0.1	0.3	0.5	0.4	0.4	0.1
Nonlinear frequency conversion	1.71		1.1	1.6	1.6	0.9	0
High-resolution lidar	1.73		0.2	0.2	0.3	0.4	0.4
Differential absorption measurements	1.73		0.3	0.8	0.8	0.6	0
Gas filter correlation radiometer	1.81		0.5	1.0	1.0	1.5	0
Totals		0.1	5.95	8.5	11.6	13.2	8.5

N. BARNES

ADVANCED SENSOR CONCEPTS--SEMICONDUCTOR LASER ARRAYS

SCOPE

DEVELOP GaAlAs LASER DIODE ARRAY FOR PUMPING MIDINFRARED SOLID STATE LASERS.

OBJECTIVE

- PROVIDE HIGH-EFFICIENCY PUMPS FOR MIDINFRARED LASERS.
- PROVIDE LONG-LIFE, >10^9 SHOTS, PUMPS FOR MID-INFRARED LASERS.

RATIONALE

- MIDINFRARED LASERS ARE REQUIRED FOR
  - EYE SAFETY
  - STRONG ABSORPTION FEATURES OF TRACE GASES
- HIGH-EFFICIENCY, LONG-LIFE PUMPS ARE NEEDED FOR MIDINFRARED LASERS.
- REMOTE SENSORS NEEDED FOR ATMOSPHERIC MONITORING
  - GREENHOUSE EFFECT: CO_2, CH_4
  - OZONE HOLE: O_3, CFC

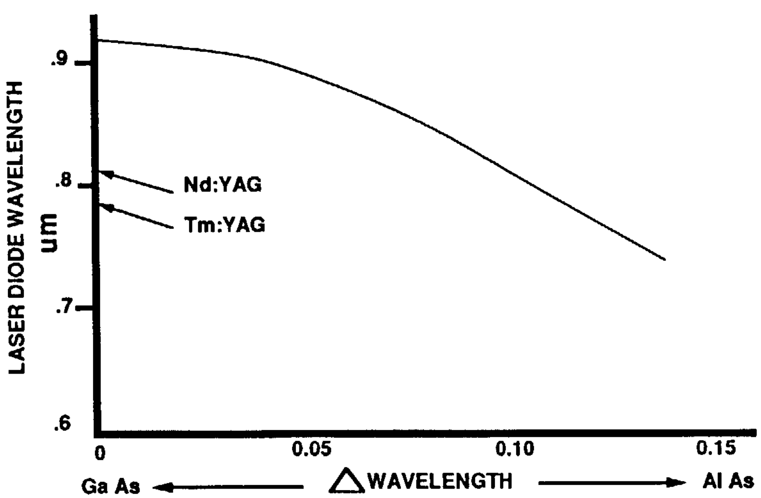
APPROACH

- UTILIZE GaAlAs LASER DIODE TECHNOLOGY.
  - GaAlAs DEVICES EMERGING FOR Nd:YAG APPLICATIONS
  - SAME TECHNOLOGY APPLICABLE FOR OTHER LASER MATERIALS.
- TAILOR LASER DIODES FOR APPLICATIONS.
  - VARY Al/Ga RATIO TO LASER DIODE WAVELENGTH
  - UTILIZE QUANTUM WELL STRUCTURE

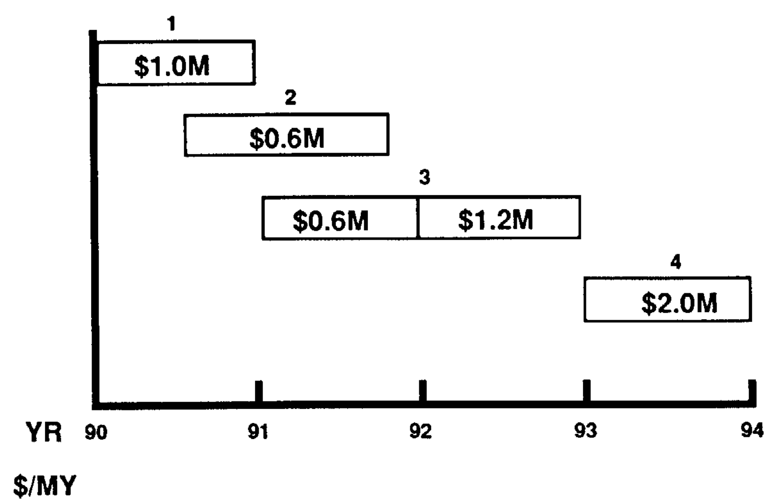
DELIVERABLES

1. EVALUATION OF QUANTUM WELL STRUCTURE.
2. EVALUATION OF SHIFT OF LASER DIODE WAVELENGTH.
3. TEST DATA ON LASER DIODE EVALUATION.
4. 1.0-CM-LONG LASER DIODE BARS.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



N. BARNS

ADVANCED SENSOR CONCEPTS--MIDINFRARED LIDAR TECHNOLOGY

SCOPE

DEVELOP THULIUM LASER TECHNOLOGY FOR MEASUREMENTS OF CONCENTRATION AND GROWTH OF ATMOSPHERIC SPECIES OVER WAVELENGTHS FROM 1 TO 10 μM.

OBJECTIVE

OBTAIN AND EVALUATE GREENHOUSE PARAMETRICS AND GROWTH, BIOMASS BURNING, VOLCANIC VENTS, INDUSTRIAL PRODUCTION, AND STRESS/REMEDY PATTERNING.

RATIONALE

IMPROVED SENSOR LIFETIMES AND NOISE DISCRIMINATION TO MEASURE ATMOSPHERIC SPECIES OVER A GLOBAL SCALE TO IMPROVE THE UNDERSTANDING OF THE SPECIES DIFFUSION AND MIGRATION PROCESSES.

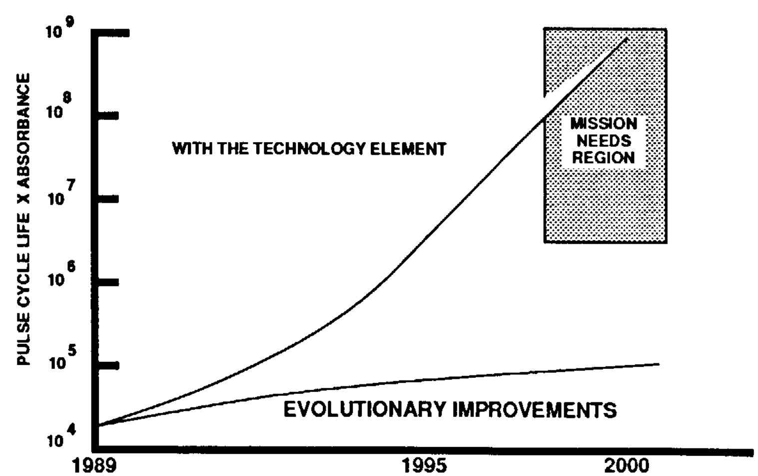
APPROACH

MATERIAL DEVELOPMENT AND SELECTION TO IMPROVE QUANTUM EFFICIENCY, RELIABILITY, AND LIFETIME. THROUGH LABORATORY VALIDATION AND SYSTEMS OPTIMIZATION, DEMONSTRATE IMPROVEMENTS AND FIGURES OF MERIT.

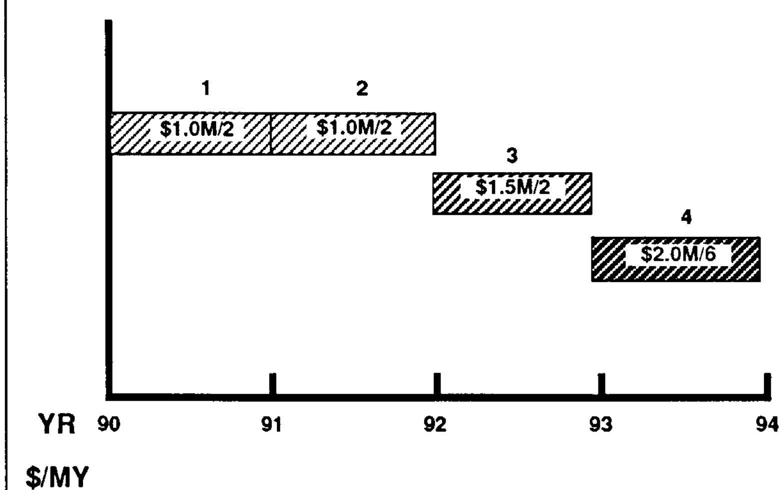
DELIVERABLES

1. REPORT ON BEST CANDIDATE GARNET STRUCTURE MATERIAL; SELECT CANDIDATE MATERIAL.
2. LABORATORY DEMONSTRATION OF TUNABILITY OVER THE CRITICAL WAVENUMBERS OF INTEREST.
3. DELIVERY OF LABORATORY SAMPLES AND EVALUATION REPORT.
4. DEMONSTRATE TECHNOLOGY AND APPLICATIONS.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



R. NELMS

COHERENT DOPPLER LIDAR (WIND SENSING)

SCOPE

DEVELOP SOLID-STATE EYE-SAFE LASER TECHNOLOGY FOR MEASUREMENT OF WIND VELOCITY (WIND FIELD VECTORS) FROM EARTH ORBIT.

OBJECTIVE

- GLOBAL MEASUREMENT OF WIND VELOCITY TO IMPROVE UNDERSTANDING OF CLIMATE AND POLLUTANT TRANSPORT MECHANISMS.
- PROVIDE SOLID-STATE (LONG-LIFE) LASER TECHNOLOGY COMPATIBLE WITH LAUNCH AND SPACE ENVIRONMENTS.
- OPTIMIZE SOURCE WAVELENGTH TO PARTICLE SIZE FOR MAXIMUM DETECTABILITY WITHIN EYE-SAFE SPECTRUM.

RATIONALE

- BETTER MATCH BETWEEN PARTICLE SIZE DISTRIBUTION AND WAVELENGTH - IMPROVED PERFORMANCE .
- TUNABLE TO WATER ABSORPTION SPECTRUM - PROVIDING EYE-SAFE OPERATION
- COHERENT DETECTORS FOR THE 1- TO 2-MICRON REGION REQUIRE LESS ONBOARD SUPPORT (COOLING, etc.) AND PROVIDE HIGHER SENSITIVITY.

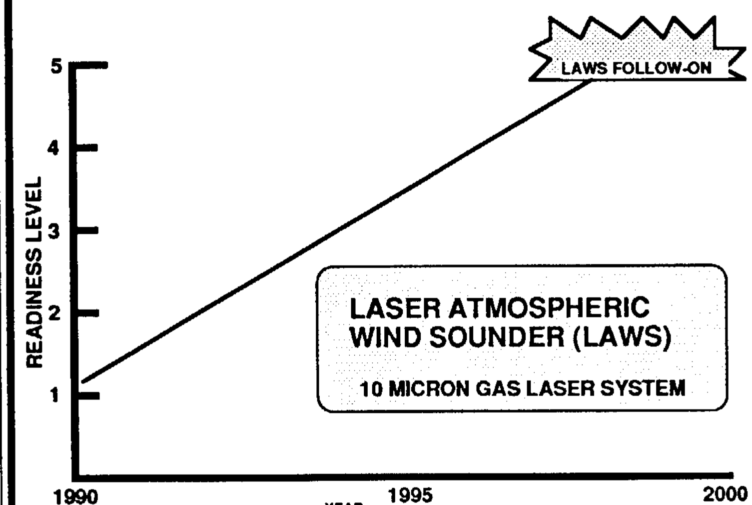
APPROACH

- DEVELOP A 2-MICRON LIDAR SOURCE, BASED ON TECHNOLOGY EFFORT INITIATED UNDER OAST/AERO WIND SHEAR PROGRAM.
- DEVELOP COHERENT DETECTOR/SENSOR SYSTEMS FOR THE 2-MICRON REGION
- INTEGRATE THESE SYSTEMS AND DEMONSTRATE SYSTEM-LEVEL TECHNOLOGY FOR A FOLLOW-ON TO THE EOS LAWS SYSTEM.

DELIVERABLES

1. TECHNOLOGY ASSESSMENT FOR LASER AND COHERENT DETECTOR/SENSOR SYSTEMS
2. CONCEPT DEVELOPMENT
3. DEVELOP AND DEMONSTRATE LASER SYSTEM
4. DEVELOP AND DEMONSTRATE COHERENT DETECTOR/SENSOR TECHNOLOGY
5. DEVELOP AND DEMONSTRATE DOPPLER LIDAR SYSTEM

TECHNOLOGY ASSESSMENT



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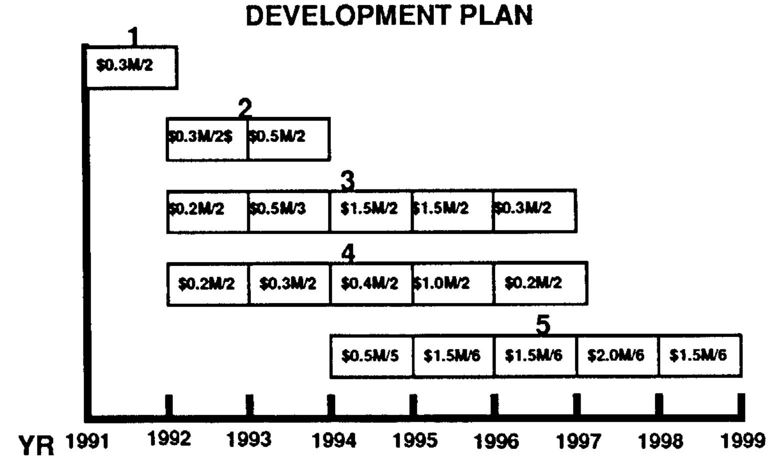
WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



$/MY								
	$ 0.3M	$ 0.7	$1.3M	$ 2.4M	$ 4.0M	$ 2.0M	$ 2.0M	$ 1.5M
	2	6	7	9	10	10	6	6

NASA-LaRC

CARBON DIOXIDE LASER CATALYST

P. BROCKMAN

SCOPE

Develop technology to provide high-efficiency, ambient temperature, CO-O_2 recombination catalysts for long-life, closed cycle operation of pulsed common and rare isotope CO_2 lasers.

OBJECTIVE

- Develop high-efficiency, ambient temperature CO-O_2 recombination catalysts.
- Develop technology to allow the use of these catalysts with rare isotope laser gases.
- Demonstrate long-lifetime operation of these catalysts.

RATIONALE

The Laser Atmospheric Wind Sounder (LAWS) program and other space-based remote sensing programs will depend on high-energy pulsed CO_2 lasers. The operation of these lasers results in breakdown of the CO_2 into CO and O_2 with subsequent laser degradation and failure. The catalysts recombine these gases and allow long-lifetime operation without replacing the laser gas.

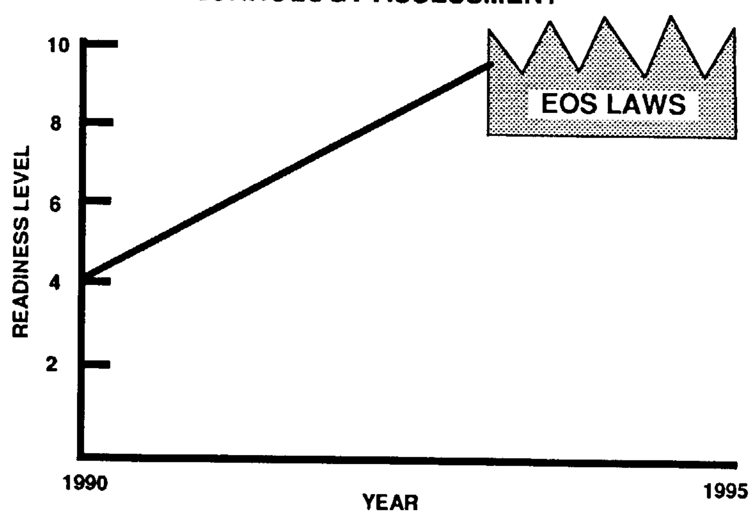
APPROACH

Continue the current research effort in noble-metal/reducible-oxide materials to achieve the maximum catalyst activity with minimum decay for long-lifetime CO_2 laser operation. The catalyst will be developed to be fully compatible with rare isotope operation, and the mechanism of operation will be modeled to allow reliable predictions of long-life behavior. This will be tested in lasers and surrogate facilities.

DELIVERABLES

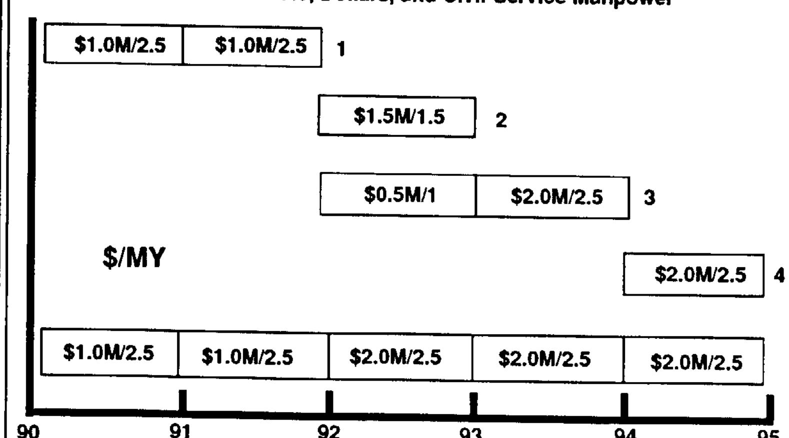
1. Formulation for high-efficiency long-life catalyst.
2. Computer models of catalyst mechanisms and long-life behavior.
3. Long-life tests of catalyst behavior.
4. Catalyst for LAWS flight instrument.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN

Schedule, Dollars, and Civil-Service Manpower



R. NELMS

ADVANCED SENSOR CONCEPTS--SCANNING LIDAR TECHNOLOGY

SCOPE

DEVELOP AND DEMONSTRATE DESIGN CONCEPT(S) TO ENABLE SCANNING LIDAR SYSTEMS WHICH CAN PROVIDE COVERAGE OVER THE EARTH'S DISC. CONCEPT STUDIES WILL CONSIDER FOCAL-PLANE SCANNING, OPTICAL ELEMENT SCANNING, AND MECHANICAL SCANNING TECHNIQUES.

OBJECTIVE

PRODUCE REAL-TIME SYNOPTIC MAPS OF UPPER ATMOSPHERIC SPECIES TO DETERMINE CAUSE AND EFFECT FACTORS RELATING TO ATMOSPHERIC CONSTITUENT DISTRIBUTIONS.

RATIONALE

PRESENT TECHNOLOGY GENERATES: (1) SINGLE-POINT MEASUREMENTS OF SPECIES DISTRIBUTIONS THAT DO NOT PRODUCE MAPS IN A COMPREHENSIVE AND TIMELY MANNER, AND (2) DATA THAT DO NOT PERMIT ADEQUATE INCLUSION, INTERPRETATION, OR UNDERSTANDING OF ANOMALOUS ATMOSPHERIC PERTURBATIONS.

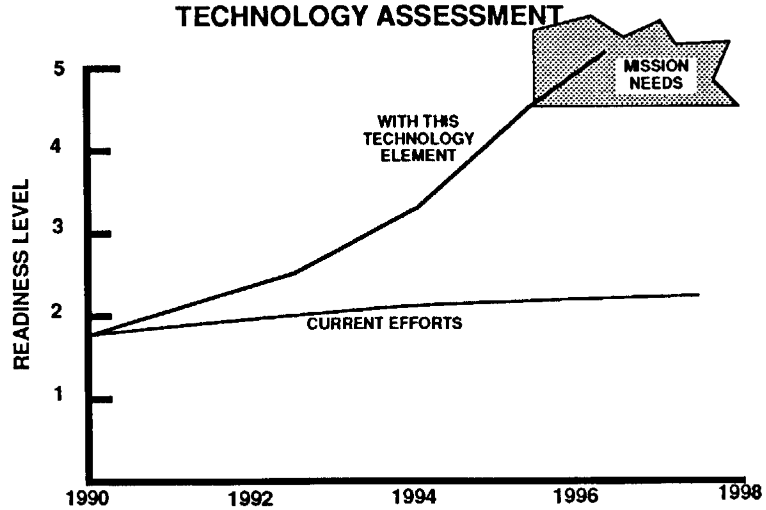
APPROACH

USE EXISTING LIDAR TECHNOLOGY AS A PRECURSOR AND DESIGN TOOL. A SCANNING LIDAR SYSTEM WILL BE DESIGNED AND IMPLEMENTED WITH IMPROVED OPTICS, DETECTORS, ELECTRONICS, AND POINTING CONTROL TO DEMONSTRATE FEASIBILITY.

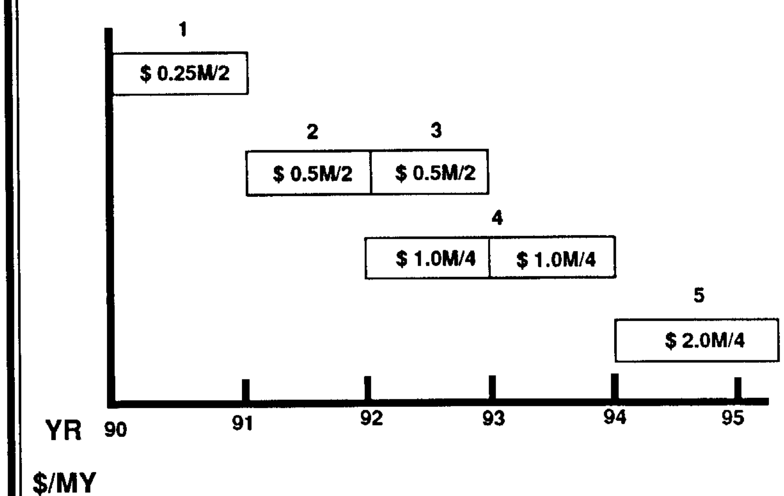
DELIVERABLES

1. SCANNING LIDAR SYSTEM DEFINITION AND COMPONENT TECHNOLOGY REQUIREMENTS.
2. OPTICS AND COMPONENT ANALYSIS AND DEFINITION.
3. IMPROVED POINTING SYSTEM.
4. IMPROVED COMPONENT TECHNOLOGY.
5. LABORATORY DEMONSTRATION.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



J. GOAD

ADVANCED SENSOR CONCEPTS--LASER WAVEMETER AND CALIBRATION TECHNOLOGY

SCOPE

TO DEVELOP TECHNOLOGY TO PROVIDE WAVELENGTH KNOWLEDGE TO CONTROL ELEMENT TUNED AND INJECTION (SEEDED) TUNED SOLID-STATE LASERS.

OBJECTIVE

TO DEVELOP:
1. HIGH-SPEED SELF-CORRECTING DATA RETRIEVAL ALGORITHMS.
2. MONOLITHIC FABRY-PEROT INTERFEROMETERS.
3. THERMO-MECHANICAL STABLE SUPPORTING STRUCTURES
4. HIGHLY ACCURATE CALIBRATION TECHNIQUES.
5. BROAD-WAVELENGTH HIGH-REFLECTIVITY COATINGS.

RATIONALE

ADVANCED WAVELENGTH KNOWLEDGE IS NEEDED FOR:

1. ELEMENT TUNED AND INJECTION TUNED SOLID-STATE LASERS.
2. DIAL MEASUREMENTS OF H_2O, O_3, TEMPERATURE, PRESSURE, AND AEROSOLS.
3. EARTH AND ATMOSPHERIC REMOTE SENSING.

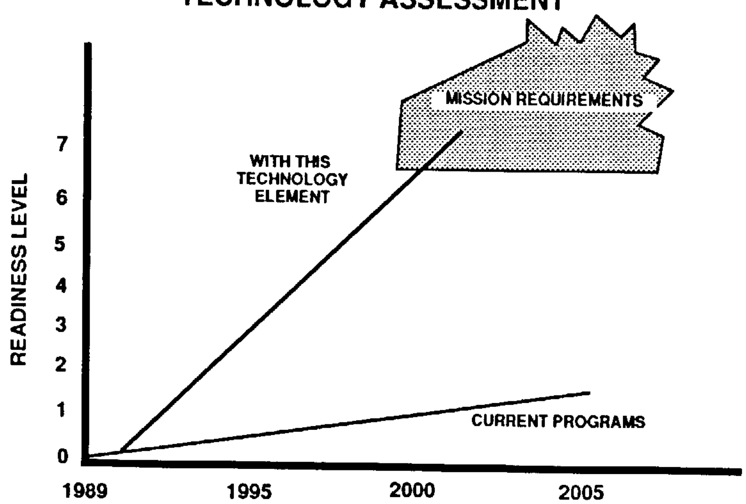
APPROACH

USE FABRY-PEROT INTERFEROMETRY WITH SELF-CORRECTING DATA RETRIEVAL ALGORITHMS RUNNING IN ADVANCED COMPUTERS TO PROVIDE HIGHLY ACCURATE LASER WAVELENGTH CENTROID DATA.

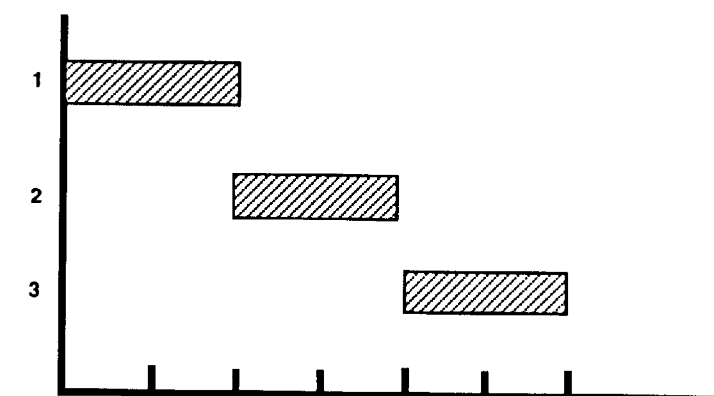
DELIVERABLES

1. END-TO-END INSTRUMENT MODEL THAT VALIDATES APPROACH.
2. OPERATE BREADBOARD THAT DEMONSTRATES LASER WAVELENGTH CENTROID RETRIEVAL TO SEVERAL HUNDREDTHS OF A PICOMETER.
3. HIGH-SPEED COMPUTER DEMONSTRATION.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



YR	90	91	92	93	94	95	
$/MY	0.1/2	0.3/3	0.5/4	0.4/4	0.4/3	0.1/2	

N. BARNS

ADVANCED SENSOR CONCEPTS-NONLINEAR FREQUENCY CONVERSION TECHNOLOGY

SCOPE

DEVELOP NONLINEAR FREQUENCY CONVERSION TECHNOLOGY FOR THE MIDINFRARED REGION BETWEEN 2.5 AND 12.0 μm.

OBJECTIVE

- PROVIDE HIGH-EFFICIENCY FREQUENCY CONVERSION TECHNIQUES.
- PROVIDE LASER SOURCE TUNABLE BETWEEN 2.5 AND 12.0 μm.
- PROVIDE SINGLE-FREQUENCY LASER SOURCE.

RATIONALE

- MIDINFRARED LASERS ARE REQUIRED FOR REMOTE SENSORS.
  - EYE SAFETY CONSIDERATIONS
  - STRONG ABSORPTION FEATURES OF TRACE GASES
- SOLID-STATE LASERS DO NOT OPERATE MUCH BEYOND 2.1 μm.
- SOLID-STATE FREQUENCY CONVERTER COULD PROVIDE A TUNABLE SOURCE BETWEEN 2.5 AND 12.0 μm.

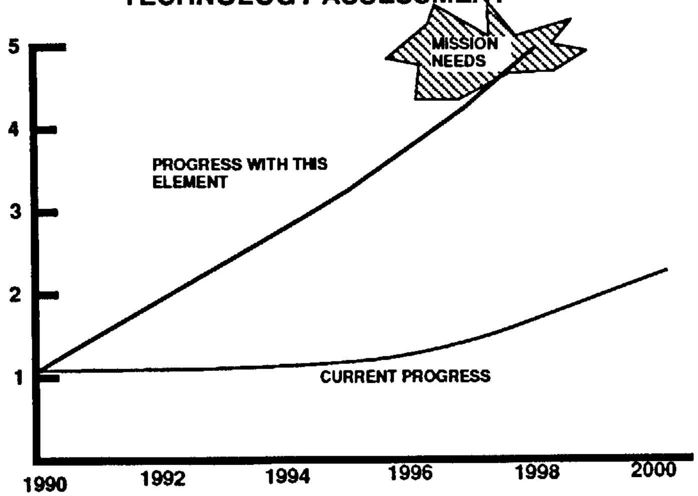
APPROACH

- UTILIZE MIDINFRARED LASERS AS PUMP SOURCE.
  - FLASHLAMP-PUMPED LASERS FOR INITIAL DEMONSTRATION
  - LASER-DIODE-PUMPED LASERS EVENTUALLY
  - ALLOWS PARALLEL DEVELOPMENT
- DEVELOP/EVALUATE AVAILABLE NONLINEAR MATERIALS.
  - $AgGaSe_2$ EVALUATE
  - $ZnGaP_2$ DEVELOP/EVALUATE
- CONSTRUCT/DEMONSTRATE FREQUENCY CONVERSION DEVICES.
  - OPTICAL PARAMETRIC OSCILLATOR
  - OPTICAL PARAMETRIC AMPLIFIER

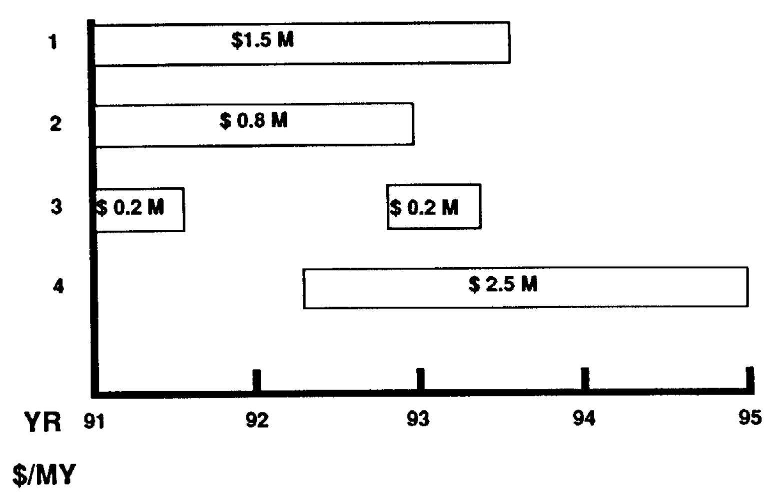
DELIVERABLES

1. DEVELOP $ZnGaP_2$ CRYSTALS.
2. EVALUATION OF NONLINEAR MATERIALS.
3. OPTICAL PARAMETRIC AMPLIFIER.
4. OPTICAL PARAMETRIC OSCILLATOR.
   - BROADBAND
   - SINGLE FREQUENCY

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



HIGH-RESOLUTION LIDAR

E. MADARAS

SCOPE

DEVELOP ADVANCED OPTICAL METHODS FOR ATMOSPHERIC MONITORING.

OBJECTIVE

- PROVIDE CAPABILITY TO MAP OUT ATMOSPHERIC INFORMATION WITH HIGH-RESOLUTION RANGE SENSING

RATIONALE

- A PHASE SENSITIVE MEASUREMENT SYSTEM WILL ALLOW MORE ACCURATE RANGE RESOLUTION THAN IS CURRENTLY CAPABLE ON LIDAR ALONE.
- WE HAVE DEMONSTRATED A LASER PHASE SENSITIVE MEASUREMENT SYSTEM WITH RANGE ACCURACIES OF ONE PART IN A MILLION.
- COUPLING LIDAR WITH A PHASE SENSITIVE MEASUREMENT SYSTEM COULD IMPROVE LIDAR CAPABILITIES SIGNIFICANTLY.

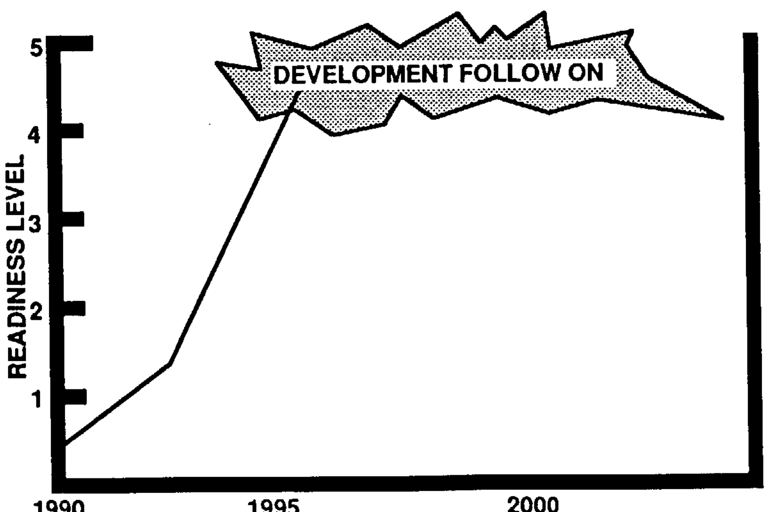
APPROACH

- CONSTRUCT A RADAR FREQUENCY PULSE, PHASE LOCK LOOP SYSTEM THAT IS ALSO A PART OF A LIDAR SYSTEM.
- EVALUATE THE SYSTEM FROM A GROUND-BASED SYSTEM.

DELIVERABLES

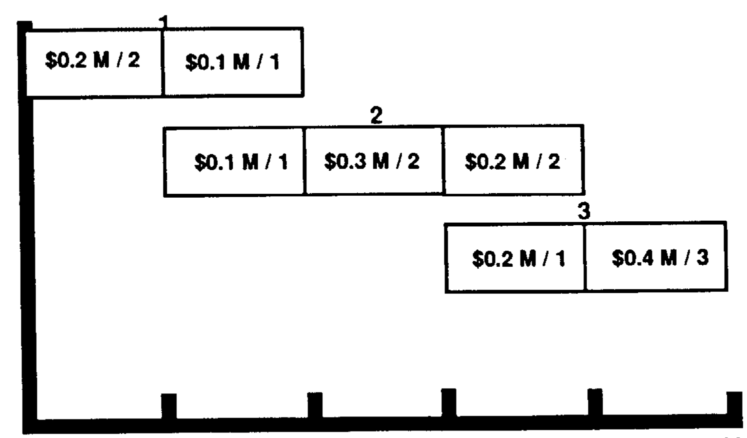
1. DEVELOPMENT OF TECHNOLOGY FOR RADAR SYSTEM.
2. DEVELOPMENT OF RADAR-PULSED, PHASE LOCK LOOP/LIDAR LAB SYSTEM.
3. EVALUATION OF SYSTEM.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



YR	1991	1992	1993	1994	1995
$/MY	$0.2 M	$0.2 M	$0.3 M	$0.4 M	$0.4 M
	2	2	2	3	3

G. SACHSE

ADVANCED SENSOR CONCEPTS-- DIFFERENTIAL ABSORPTION MEASUREMENTS

SCOPE

DEVELOPMENT AND DEMONSTRATION OF IMPROVED SEMICONDUCTOR DIODE LASERS FOR IN SITU, HIGH SENSITIVITY MEASUREMENTS OF TRACE ATMOSPHERIC SPECIES.

OBJECTIVE

DEVELOP AND DEMONSTRATE HIGHLY RELIABLE, SINGLE MODE, HIGH TEMPERATURE (>100K) SEMICONDUCTOR DIODE LASERS FOR THE 2 TO 15 MICRON SPECTRAL REGION.

RATIONALE

IN SITU MEASUREMENTS OF THE CONCENTRATION AND FLUX OF KEY TRACE SPECIES WOULD SERVE AS VALUABLE INPUTS TO ATMOSPHERIC MODELS THAT WILL PROVIDE A BETTER UNDERSTANDING OF IMPORTANT ATMOSPHERIC PROCESSES SUCH AS THE GREENHOUSE EFFECT, OZONE DEPLETION, ETC.

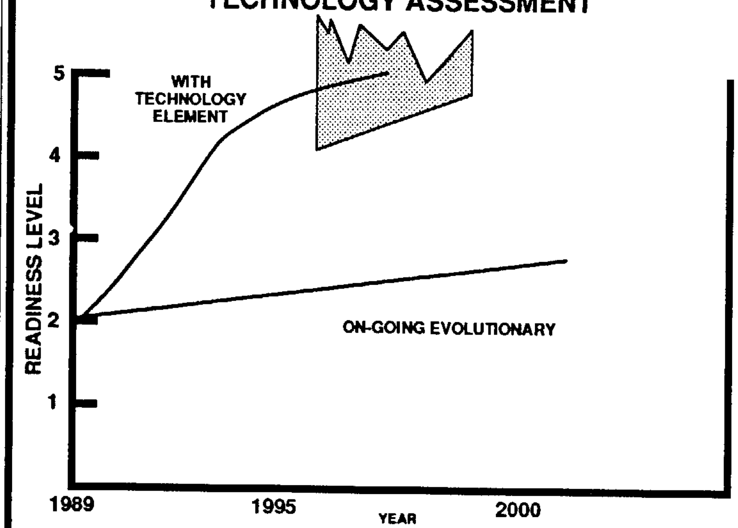
APPROACH

IMPROVE DIODE LASER MATERIAL GROWTH USING STATE-OF-THE-ART SEMICONDUCTOR TECHNOLOGIES SUCH AS MOLECULAR BEAM AND LIQUID PHASE EPITAXY. TRANSFER DIODE LASER FABRICATION TECHNOLOGY PREVIOUSLY DEVELOPED FOR OPTICAL COMMUNICATIONS TO THE DIODE LASER MATERIALS SUITED FOR THE MID IR.

DELIVERABLES

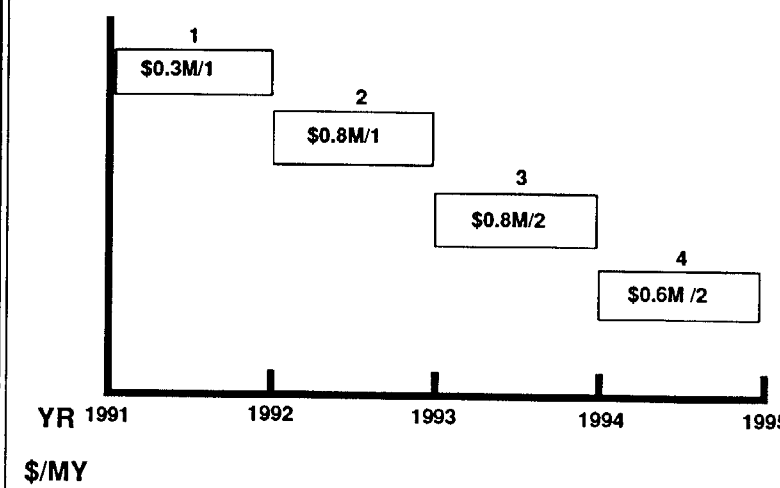
1. MODEL LASER RELIABILITY AND LIFETIME DRIVERS.
2. IMPROVE CRYSTAL GROWTH TECHNOLOGY.
3. IMPROVE DIODE LASER FABRICATION TECHNOLOGY.
4. PERFORMANCE AND RELIABILITY EVALUATIONS.
5. DELIVER LASERS FOR SYSTEM DEMONSTRATIONS.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



G. SACHSE

GAS FILTER CORRELATION RADIOMETER

SCOPE

DEVELOP AND DEMONSTRATE A NEW SOLID-STATE GAS FILTER CORRELATION RADIOMETER (GFCR) CONCEPT FOR SPACEBORNE SENSING OF TROPOSPHERIC TRACE GASES.

OBJECTIVE

- DEMONSTRATE FEASIBILITY OF SOLID-STATE GFCR CONCEPT
- AIRCRAFT VALIDATION OF GFCR CONCEPT
- INSTRUMENT SYSTEM CONCEPT DEVELOPMENT FOR SPACE-FLIGHT APPLICATIONS

RATIONALE

- ENABLE MEASUREMENT OF GLOBAL DISTRIBUTION OF TRACE GASES NEEDED IN THE STUDY OF ENVIRONMENTAL CONCERNS (GREENHOUSE PROCESSES, OZONE DEPLETION, ETC.)
- POTENTIAL FOR SIGNIFICANTLY HIGHER SENSITIVITY IN REMOTE SENSING OF MANY TROPOSPHERIC GAS SPECIES.
- HIGHER RELIABILITY AND LIFETIME THROUGH ELIMINATION OF HIGH-RATE MOVING COMPONENTS.

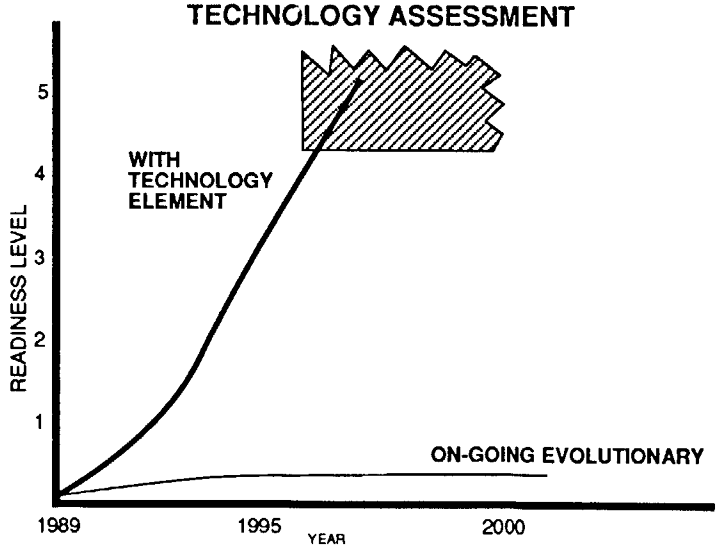
APPROACH

- ANALYZE GAS FILTER CORRELATION RADIOMETER CONCEPT WHICH UTILIZES "OPTICAL PATH MODULATION" APPROACH INVOLVING SOLID-STATE POLARIZATION LIGHT MODULATORS.
- PERFORM LABORATORY DEMONSTRATION OF GFCR CONCEPT.
- DEVELOP AND TEST PROTOTYPE GFCR SYSTEM ON AIRCRAFT PLATFORM.
- EXECUTE DESIGN STUDY FOR A SPACEFLIGHT INSTRUMENT.

DELIVERABLES

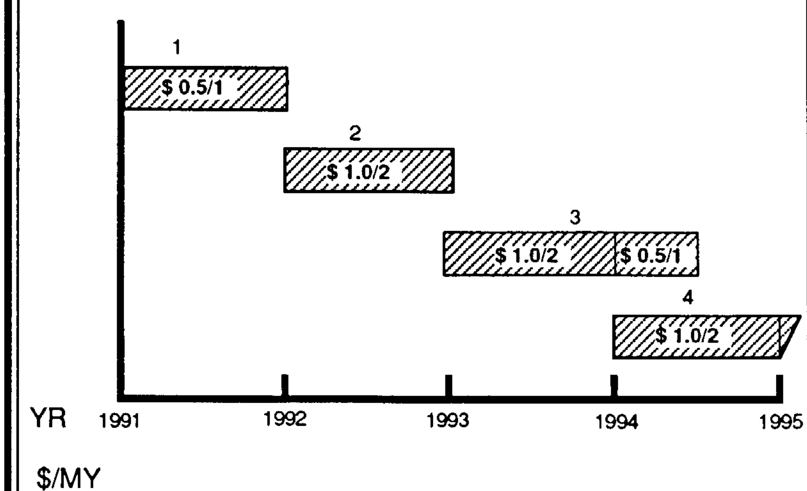
1. STUDY/ANALYSIS OF SOLID-STATE GAS FILTER CORRELATION APPROACH
2. LABORATORY DEMONSTRATION OF THE SOLID-STATE GFCR CONCEPT.
3. DEVELOPMENT AND FLIGHT DEMONSTRATION OF AN AIRCRAFT GFCR SYSTEM.
4. DESIGN STUDY FOR A SPACECRAFT INSTRUMENT.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



LaRC GCTI Observation Technologies

1.8 Calibration

Technology	NASA GCTI WBS	Proposal funding requirements, millions of dollars					
		FY90	FY91	FY92	FY93	FY94	FY95
Earth radiation instrument calibration facility	1.81		1.5	1.1	0.2		
Totals			1.5	1.1	0.2		

EARTH RADIATION INSTRUMENT CALIBRATION FACILITY

L. TAYLOR

SCOPE

Provide a calibration facility, including thermal vacuum chamber, sources, on-line control and data system, and methodology for simultaneous ground and in-flight calibration under simulated mission environments.

OBJECTIVE

- Provide a key enabling capability for the EOS CERES instrument system.
- Provide a sustained NASA calibration capability which is adaptable to a number of spaceflight and aircraft atmospheric research instrument systems.

RATIONALE

NASA ownership key to multiproject utilization and long-term upgrade and evolution of such a facility.

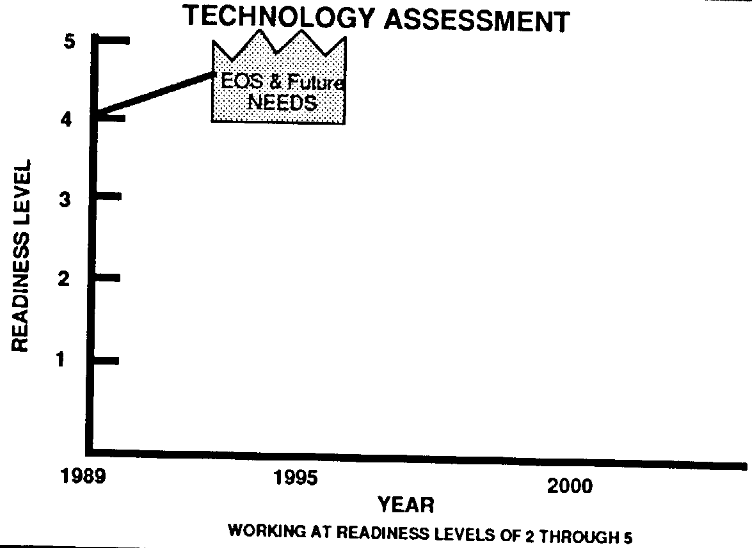
APPROACH

Utilize the system concept and a major part of the hardware design from the calibration facility which was developed under the Earth Radiation Budget Experiment (ERBE), and which was key to the success of the ERBE mission.

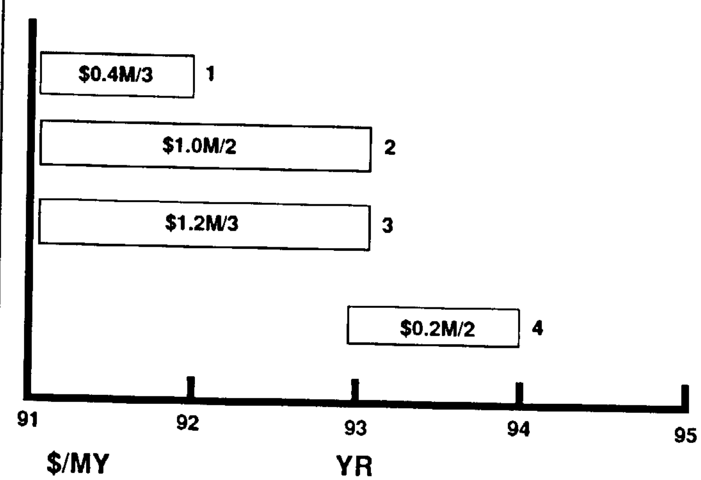
DELIVERABLES

1. System Design
2. Development of Sources
3. Facility Development
4. Facility Demonstration

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



Appendix B

Spacecraft and Operations Technology Proposals (WBS 2.0)

LaRC GCTI Spacecraft Technologies

2.1 Materials

Technology	NASA GCTI WBS	Proposal funding requirements, millions of dollars					
		FY90	FY91	FY92	FY93	FY94	FY95
Materials	2.11–.13		3.6	7.2	9.7	10.6	10.0
Nondestructive evaluation (NDE):							
Fiber optics for tethers			0.2	0.2	0.3	0.5	0.5
Thermal properties for tethers			0.15	0.15	0.2	0.2	0.3
Platform materials			0.15	0.2	0.2	0.2	0.15
Sensors for structures			0.15	0.15	0.2	0.2	0.2
Totals			4.25	7.90	10.6	11.7	11.15

SPACE PLATFORM THRUST: MATERIALS ELEMENT (LaRC Role)

B. STEIN

SCOPE

DEVELOP HIGH-PERFORMANCE, LONG-LIFE STRUCTURAL MATERIALS/ COATINGS, AND CHARACTERIZE THE DURABILITY OF THESE MATERIALS IN EARTH-ORBITING ENVIRONMENTS BY MODELING, GROUND/FLIGHT TESTING, AND THE DEVELOPMENT OF ADVANCED NDE TECHNOLOGY.

OBJECTIVE

- CHARACTERIZE LONG-TERM ENVIRONMENTAL MATERIAL RESPONSE.
- DEVELOP HIGH-PERFORMANCE, SPACE-DURABLE MATERIALS/ COATINGS FOR INSTRUMENT SUPPORTS, REFLECTORS, AND LARGE PLATFORMS.
- DEVELOP ADVANCED NDE/NDI TECHNOLOGY FOR INCREASING THE RELIABILITY AND SAFETY OF EARTH-ORBITING MATERIALS AND STRUCTURES.

RATIONALE

EFFICIENT LONG-LIFE PERFORMANCE OF MATERIALS IN GEO AND LEO ENVIRONMENTS IS CRITICAL TO FUTURE LARGE GLOBAL MONITORING SPACECRAFT.

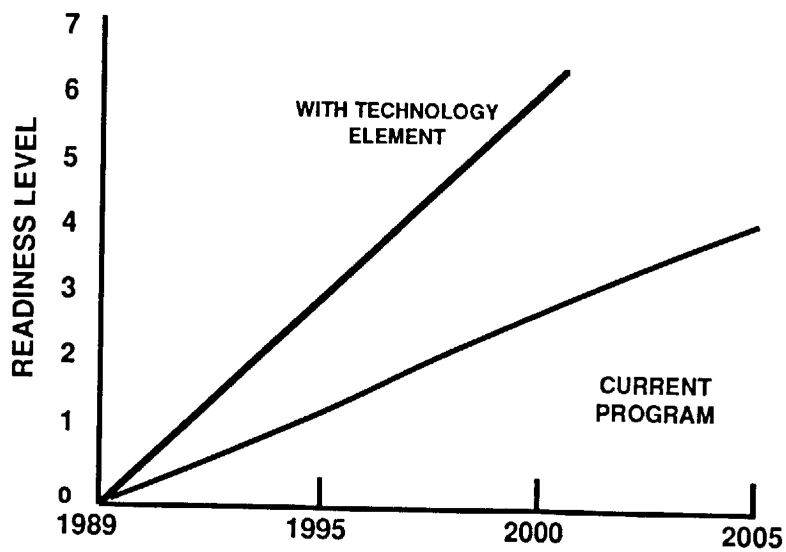
APPROACH

- ACCURATELY QUANTIFY SPACE ENVIRONMENTS AND INTERACTIONS WITH MATERIALS.
- DEVELOP LIFE PREDICTION MODELS AND VERIFY WITH GROUND/FLIGHT TEST DATA.
- DEVELOP ADVANCED HIGH-PERFORMANCE MATERIALS/ COATINGS AND DEMONSTRATE THEIR SPACE DURABILITY.
- DEVELOP TEST/VERIFICATION METHODOLOGY FOR MATERIAL INSPECTION AND PROCESS CONTROL.
- DEVELOP NDE SENSOR FOR IN SITU MONITORING OF MATERIAL/ STRUCTURE INTEGRITY.

DELIVERABLES

1. SPACE ENVIRONMENT/MATERIAL INTERACTIONS MODELS
2. ADVANCED HIGH-PERFORMANCE MATERIALS AND COATINGS
3. NDE METHODOLOGY AND INSTRUMENTATION

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN

Space Environment	1.0M	2.5M	3.0M	1.5M	1.5M
Advanced Materials	1.5M	2.0M	3.0M	4.0M	2.5M
NDE/NDI	1.1M	2.7M	3.7M	5.1M	6.0M
FY	91	92	93	94	95
$M	3.6	7.2	9.7	10.6	10.0
MY	12	16	20	20	20

Appendix B

E. MADARAS

Fiber Optical Sensors for Tether NDE

SCOPE

INTEGRATE FIBER-OPTICS SENSORS WITH TETHERS.

OBJECTIVE

- TO PROVIDE A METHOD TO MONITOR TEMPERATURE, STRAIN, ELECTRIC FIELDS, ACOUSTIC EMISSION, AND CHEMICAL DEGRADATION.

RATIONALE

- IMPROVE TETHER RELIABILITY MONITORING.
- ALLOW FOR MONITORING DURING MANUFACTURING STAGES AND THROUGHOUT DEPLOYMENT.
- AN EXCELLENT METHOD TO PROVIDE A COMMUNICATIONS LINK.

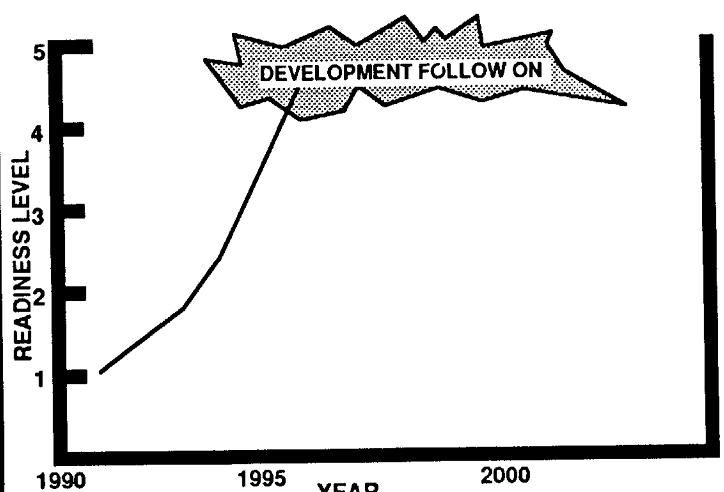
APPROACH

- DEVELOP CUSTOM FIBER FABRICATION METHODS FOR MONITORING PROPERTIES.
- DEVELOP METHODS FOR SIGNAL PROCESSING THE VARIOUS SIGNALS THAT WILL BE USED.
- DEMONSTRATE SYSTEM IN LABORATORY SETTING.

DELIVERABLES

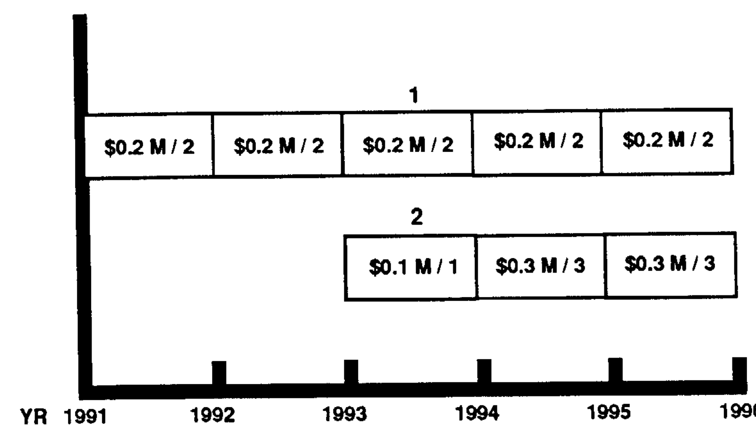
1. ADVANCED FIBERS THAT CAN BE INTEGRATED INTO TETHERS.
2. DEVELOP A PROTOTYPE SYSTEM TO VERIFY THE CAPABILITIES OF THE FIBER-OPTIC-INSTRUMENTED TETHER SYSTEM.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



$/MY					
	$0.2 M	$0.2 M	$0.3 M	$0.5 M	$0.5 M
	2	2	3	5	5

E. MADARAS

Thermal Properties NDE for Tether Materials

SCOPE
DEVELOP NDE METHODS TO MEASURE THERMAL PROPERTIES OF THERMAL MATERIALS FOR TETHERS.

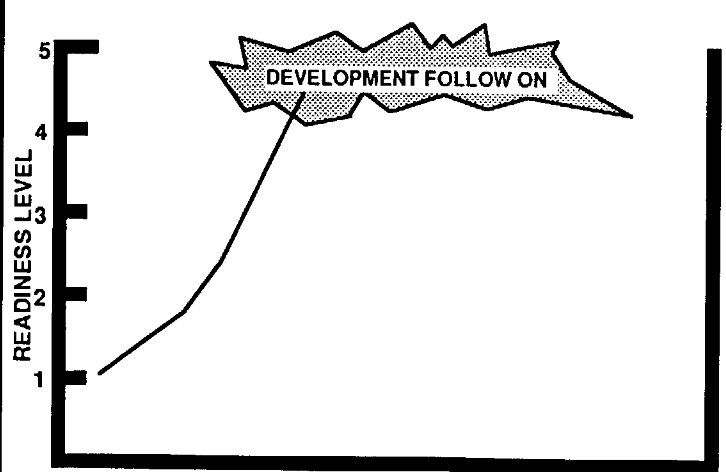
OBJECTIVE
- TO PROVIDE A METHOD TO DETERMINE THE EFFECTIVENESS OF THERMAL PROTECTION COATINGS AND DETECTION OF BOND PROBLEMS IN PROTECTIVE COATINGS.

RATIONALE
- DEVELOP A BETTER UNDERSTANDING OF TETHER THERMAL LOADS.
- IMPROVE THERMAL PROTECTIVE COATING INTEGRITY.

APPROACH
- TO EXTEND OUR CURRENT TECHNIQUES TO LOW THERMAL CONDUCTIVITY MATERIALS.

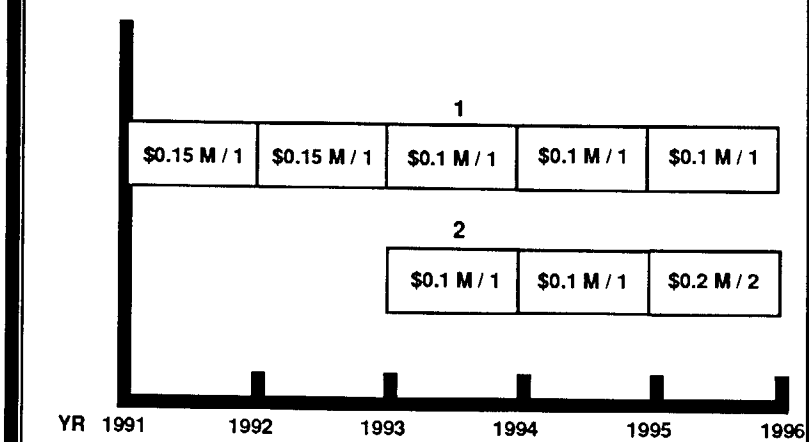
DELIVERABLES
1. A MATERIALS DATA BASE WITH RESPECT TO THE THERMAL BEHAVIOR OF TETHER MATERIALS.
2. A METHOD TO MONITOR THERMAL PROTECTIVE COATING INTEGRITY.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



$/MY					
	$0.15 M	$0.15 M	$0.2 M	$0.2 M	$0.3 M
	1	1	2	2	3

E. MADARAS

NDE for Platform Materials and Structures

SCOPE
DEVELOP A MEASUREMENT SYSTEM TO MEASURE ENGINEERING PROPERTIES THROUGHOUT CRITICAL PARTS.

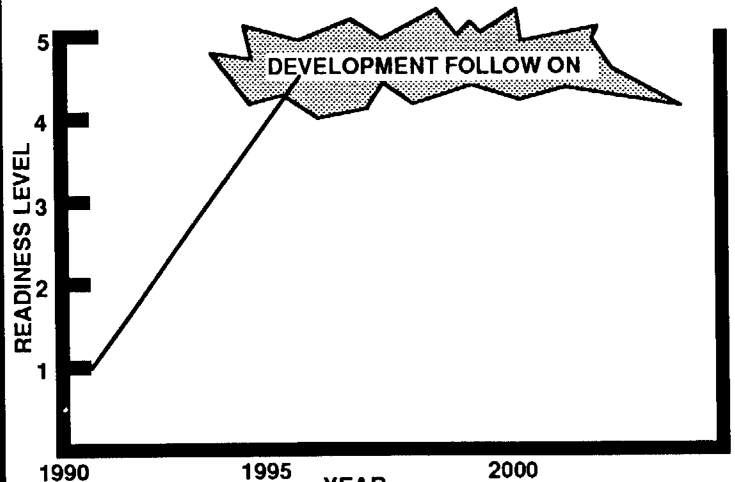
OBJECTIVE
- DEVELOP A SYSTEM TO MEASURE THE LOCAL STIFFNESS PROPERTIES OF CRITICAL MATERIALS FOR ACCURATE STRAIN PREDICTIONS.

RATIONALE
- NEED TO DEVELOP NDE METHODS THAT CAN MEASURE THE LOCAL ENGINEERING PROPERTIES OF MATERIALS.
- A MEASUREMENT SYSTEM THAT IS COUPLED WITH FINITE ELEMENT MODEL CODES COULD THEN ACCURATELY PREDICT THE BEHAVIOR OF A CRITICAL PART FOR ENHANCED SAFETY AND RELIABILTIY OF STRUCTURES.

APPROACH
- DEVELOP AN ULTRASONIC SCANNING METHOD THAT CAN MEASURE THE LOCAL STIFFNESS PROPERTIES OF MATERIALS.
- DEVELOP IMPROVED NONLINEAR COMPUTATIONAL ALGORITHMS FOR FASTER COMPUTATIONS.
- DEVELOP THE SYSTEM SO THAT IT CAN COUPLE THE LOCAL STIFFNESS VALUES INTO AN FEM CODE.

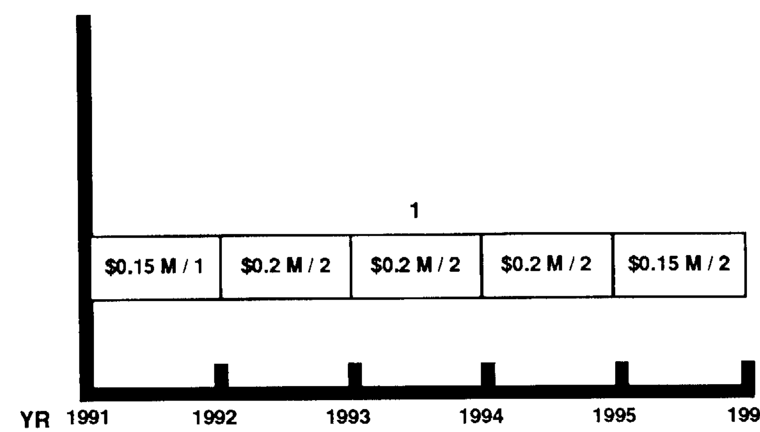
DELIVERABLES
1. A SYSTEM THAT WILL BE CAPABLE OF MEASURING THE STIFFNESS MODULI OF MATERIALS RAPIDLY AND WILL BE COUPLED TO A STANDARD FEM CODE.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



$/MY					
	$0.15 M	$0.2 M	$0.2 M	$0.2 M	$0.15 M
	1	2	2	2	2

E. MADARAS

Advanced NDE Sensors for Critical Structures

SCOPE

DEVELOP EFFICIENT THERMOELASTIC INSPECTION SYSTEM.

OBJECTIVE

- TO ENHANCE SAFETY AND RELIABILITY OF STRUCTURES USING A RAPID INSPECTION TECHNIQUE.

RATIONALE

- IMPROVE THE COST AND SPEED OF AN INSPECTION.
- NEED TO INSPECT LARGE AREAS RAPIDLY.
- DESIRABLE TO HAVE NONCONTACTING METHODS FOR NDE ON ORBIT.

APPROACH

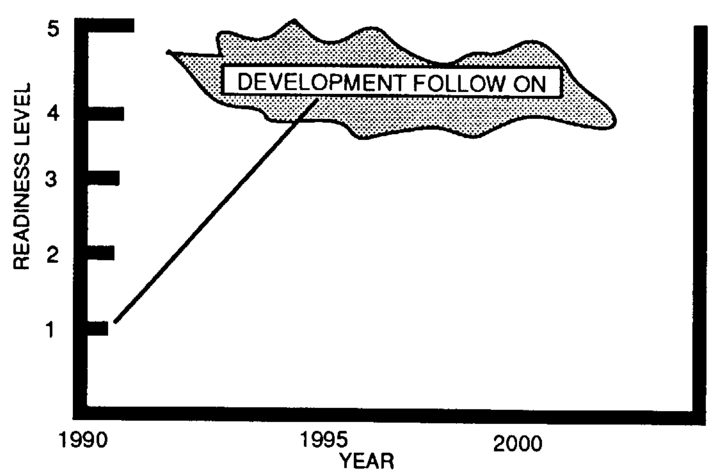
- DEFINE RELATIONSHIP BETWEEN DEFECT TYPES AND THERMOELASTIC MEASUREMENTS.
- DEVELOP THE HARDWARE AND SOFTWARE FOR FASTER INSPECTION SPEED WITH REDUCED COST.
- DEMONSTRATE SYSTEM AND LABORATORY SETTING.

DELIVERABLES

1. DATA BASE RELATING DEFECT TYPES AND THERMOELASTIC MEASUREMENTS.

2.. DEVELOP A PROTOTYPE SYSTEM TO VERIFY THE CAPABILITIES OF THE THERMOELASTIC SYSTEM.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN

	1991–1992	1992–1993	1993–1994	1994–1995	1995–1996
1	$0.05M / .5	$0.05M / .5	$0.05M / .5	$0.1M / 1	$0.1M / 1
2	$0.1M / 1	$0.1M / 1	$0.15M / 1	$0.1M / 1	$0.1M / 1

YR 1991 1992 1993 1994 1995 1996

$/MY					
	$0.15M	$0.15M	$0.2 M	$0.2 M	$0.2 M
	1.5	1.5	1.5	2	2

LaRC GCTI Spacecraft Technologies

2.2 Structures and Control

Technology	NASA GCTI WBS	Proposal funding requirements, millions of dollars					
		FY90	FY91	FY92	FY93	FY94	FY95
Structures	2.21		2	4	7.5	9	
Pointing dynamics and control	2.22		6	6	8	12	15
Totals			8	10	15.5	21	15

L. PINSON

SPACECRAFT/PLATFORM THRUST - STRUCTURES

SCOPE

Develop components and stable platform/precision payload concepts to enable construction and operation of large Earth science platforms and precision reflectors with emphasis on geostationary applications.

OBJECTIVE

To develop new high-performance structures for platform/precision reflectors which enable multiple payload/platform combinations for 20 m - 80 m deployable mesh reflectors up to 40 GHZ, 10 m - 40 m solid surface reflectors to 220 GHZ, 10 m - 20 m deployable reflectors up to 90 GHZ, and other precision payloads.

RATIONALE

Current technology for 20 m - 30 m mesh antennas limited to less than 30 GHZ. For 200 GHZ, size is limited to 4 m. Interaction of multiple precision payloads will further limit system performance. Cannot presently validate in Earth environment. Need 20 - 30 percent weight reduction.

APPROACH

Develop erectable and deployable concepts appropriate to 6 GHZ - 220 GHZ frequency range for reflectors and their combination with platforms.

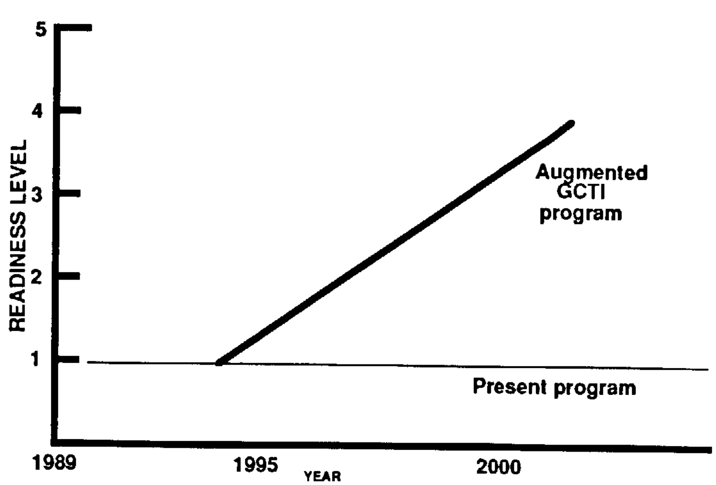
Enhance thermal, isolation, damping, and precision alignment characteristics by both passive and active means.

Enhance analysis and ground test methodology and perform ground tests.

DELIVERABLES

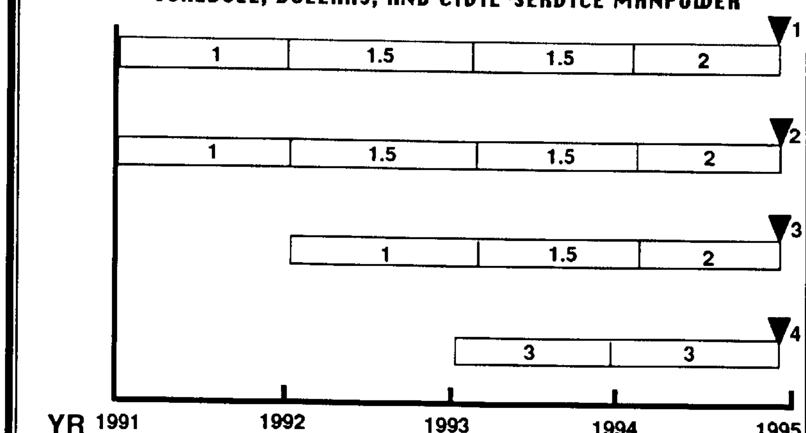
1. Demonstrate 10 - 20 m, 40 - 90 GHZ deployable reflectors.
2. Demonstrate 25 - 40 m, 220 GHZ erectable reflectors.
3. Demonstrate platform bus structure and feed mast.
4. Demonstrate large (100 m) class deployable mesh reflector.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN

SCHEDULE, DOLLARS, AND CIVIL-SERVICE MANPOWER



$M	2	4	7.5	9
MY	5	7	9	12

POINTING, DYNAMICS, AND CONTROL (PD&C)

SCOPE

Develop and demonstrate precision pointing and stabilization concepts and components for integrated multipayload pointing.

OBJECTIVE

Establish enabling technology for the integrated design and implementation of precision control techniques of multiuser platforms and attendant payloads.

RATIONALE

Current pointing capability for multipayload spacecraft is limited to hundreds of arcseconds. Interaction between payloads provides further degradation. Need technology which will result in accuracies of a few arcseconds (approx. 3) with sub-arcsecond stability.

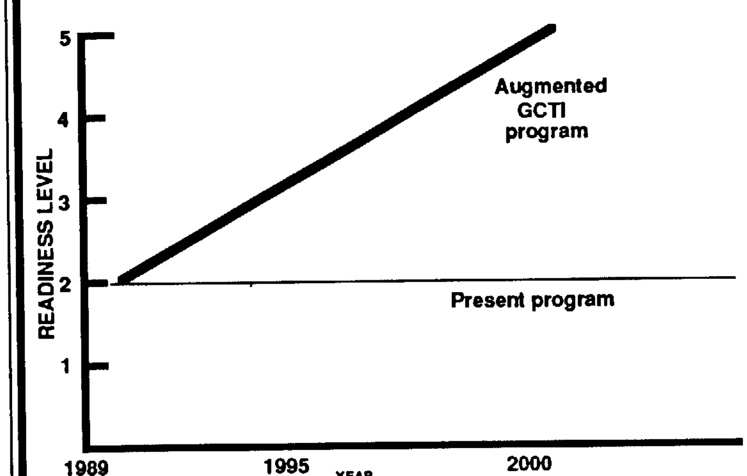
APPROACH

Acquire requirements; develop concepts, analysis and design methodology, and integrated system architecture for multiuser platforms and attendant payloads. Develop precision optical sensor/processors and payload auxiliary pointers for sub-arcsecond pointing and stabilization of science payloads. Integrate and demonstrate technologies through simulation and PD & C test bed.

DELIVERABLES

1. Integrated system design tools.
2. PD&C simulation.
3. Feature assisted pointing.
4. Auxiliary pointer for precision pointing and stabilization.
5. Advanced optical sensor/processor.
6. Technology readiness for multiuser platforms.

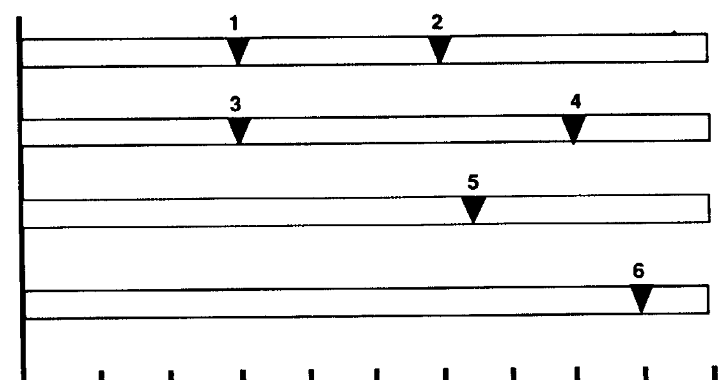
TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN

SCHEDULE, DOLLARS, AND CIVIL-SERVICE MANPOWER



YR	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
$M		6	6	8	12	15	14	13	13		
MY		8	10	13	15	19	17	15	15		

LaRC GCTI Spacecraft Technologies

2.3 Systems Analysis

Technology	NASA GCTI WBS	Proposal funding requirements, millions of dollars					
		FY90	FY91	FY92	FY93	FY94	FY95
Systems engineering analysis	2.31	1.5	5.5	7.0	9.0	34.0	37.0
Certification and verification	2.32		2.0	6.0	7.5	9.0	10.0
Operations	2.33		2.1	2.6	3.0	3.2	3.4
Nondestructive evaluation (NDE):							
Robotic servicing			0.3	0.25	0.2	0.25	0.25
Fastener recertification			0.15	0.15	0.15	0.15	0.05
Characterization of contaminants			0.2	0.2	0.2	0.3	0.2
Totals		1.5	10.25	16.2	20.05	46.9	50.9

SYSTEMS ENGINEERING ANALYSIS AND INTEGRATION

SCOPE

Identify technology needs/opportunities and develop integrated technology objectives for Earth science and operational systems through an end-to-end system study of overall system architecture. Conduct Phases A&B System Level Study Efforts

OBJECTIVES

- To develop an optimum mix of LEO and GEO spacecraft and platform concepts to meet the science objectives at minimum cost to the Agency.
- To determine economies of scale of spacecraft platforms and appropriate mission profiles.
- To establish the high-priority enabling and enhancing technologies necessary to meet the science requirements and implement Phases A&B R&T efforts.
- To develop the integrated multidisciplinary systems analysis software necessary to conduct trades and technology assessments.

RATIONALE

Diverse science requirements call for a number of different types of spacecraft and mission options. The GCTI spacecraft and antennas are of unprecedented size with stringent sensor performance and pointing requirements. Advanced technologies must be developed to meet these in-flight requirements. The necessary systems R&T efforts must be accomplished during Phases A&B to ensure the subsequent development of viable, low risk flight systems.

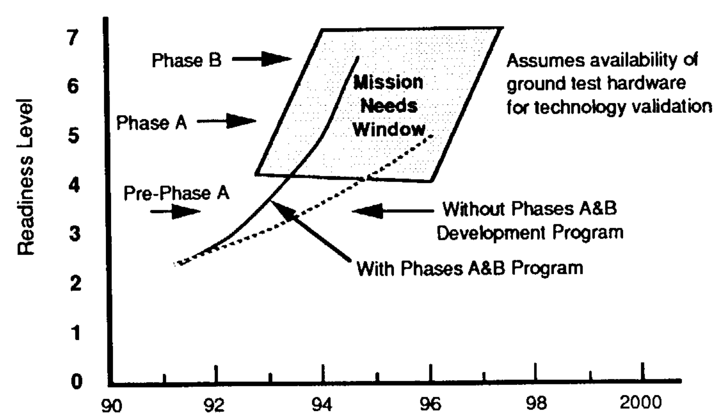
APPROACH

Interactive processes between the mission and science requirements, the spacecraft/antenna designs, and subsystem technologies are required to establish overall mission performance and to quantify the high payoff technologies.

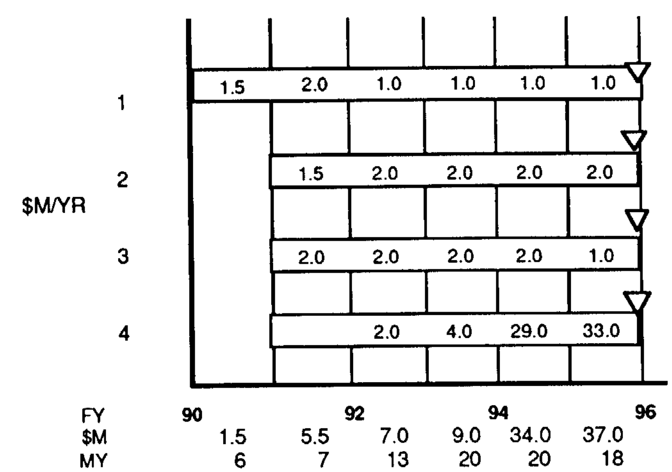
DELIVERABLES

1. End-to-end systems studies of spacecraft and antenna concepts, definition of enhancing and enabling technologies, and quantification of on-orbit performance of the system to meet the science and mission requirements.
2. Integrated multidisciplinary analysis software that couples the controls, structures, thermal, and electromagnetic technology areas with optimum spacecraft conceptual design programs to assess on-orbit performance. Does not include test hardware for validation.
3. Systems studies and trades between mission options, spacecraft concepts, and technology options.
4. Development of systems and technologies during Phases A and B.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



L. GARRETT

SPACECRAFT/PLATFORM THRUST – CERTIFICATION AND VERIFICATION

SCOPE

Certification and verification capabilities for predicting and identifying effects of environment and operations of the platform baseline throughout the integration, test, launch, and orbital lifetime.

OBJECTIVES

- Develop new ground test techniques
- Develop measurement techniques
- Methods for modeling and predicting system effects
- Coupling measured/predictions to enable corrective action

RATIONALE

- Large system cannot be ground tested
- Interactive, multiple sensors require correlative data
- Reliable, long-life operations will require knowledge, identification, and compensation to meet mission goals

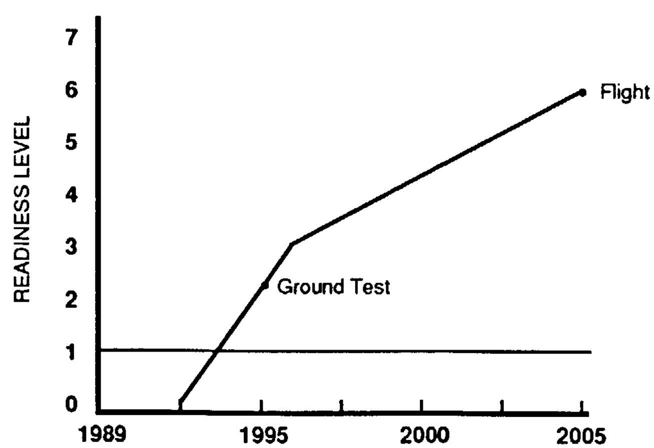
APPROACH

- Develop new test techniques.
- Develop nonintrusive measurement techniques and methods for both ground and space utilization.
- Define and establish the required modeling tasks to analyze the measurement data.
- Ground tests and flight test.

DELIVERABLES

1. New test techniques
2. Analytical methods
3. Instrument components, measurement system, data system, hardware
4. Ground test validation
5. Flight demonstration

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN

FY	90	91	92	93	94	95
New Test Methods		1	2	2	1	
Analytical Method		1	2	2	2	2
Hardware				3	3	3
Ground Tests			2		2.5	4.5
Flight				.5*	.5*	.5*
$M		2	6	7.5	9	10

*Does not include cost of flight hardware and flight

L. GARRETT

SPACECRAFT/PLATFORM OPERATIONS

SCOPE

ADVANCED TECHNOLOGY TO ACHIEVE HIGH EFFICIENCY AND EXTENDED PLATFORM LIFE.

OBJECTIVE

- STANDARD INTERFACES FOR INSTRUMENT COMPATIBILITY.
- ROBOTICS AND AUTOMATION FOR SPACECRAFT SERVICING, TEST, AND UPGRADE.
- INTERINSTRUMENT COMPATIBILITY FOR COMBINED OPERATIONS.
- ON-ORBIT INSPECTION, CLEANING, AND RESURFACING OF SENSORS AND OPTICS.
- MAXIMAL ON-ORBIT RECONFIGURATION FOR MISSION ENHANCEMENT.

RATIONALE

- NO CURRENT CAPABILITY FOR ON-ORBIT CHECKOUT, SERVICING, AND REMOTE ASSEMBLY.
- ALTERNATIVES ARE NEEDED TO EXTEND PLATFORM LIFE AND ENHANCE PERFORMANCE.

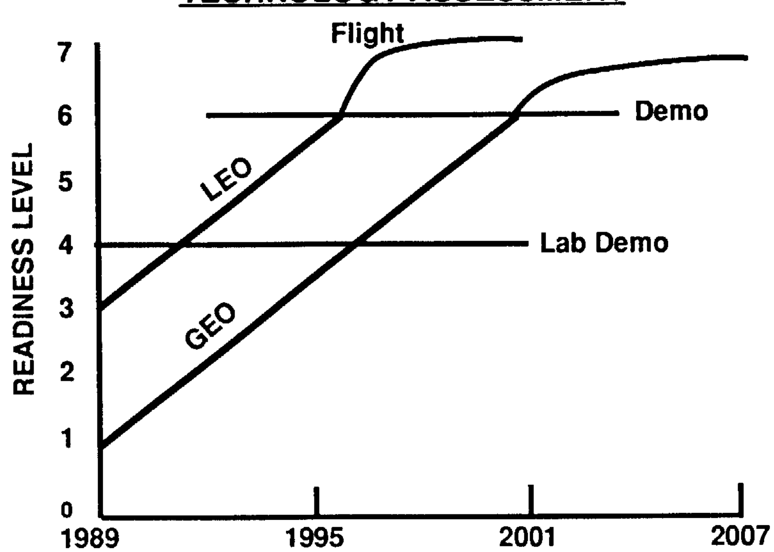
APPROACH

- REQUIREMENTS ANALYSIS, TECHNOLOGY DEVELOPMENT, AND GROUND AND ON-ORBIT TESTS OF REMOTE SERVICING, INSPECTION, REFURBISHMENT, AND PLATFORM UPGRADE.
- DEVELOP AUTOMATED METHODS FOR SCHEDULING AND SELECTION OF COMPLEMENTARY SENSOR SETS.
- DEFINE GROUND-BASED AND SPACE-BASED SUPPORT REQUIREMENTS FOR PLATFORM OPERATIONS.

DELIVERABLES

- DESIGN OF SYSTEMS FOR AUTOMATED INSPECTION, MAINTENANCE, AND SERVICING.
- INTERFACE REQUIREMENTS AND STANDARDS FOR SENSOR AND INSTRUMENTATION COMPATIBILITY.
- REFURBISHMENT MATERIALS AND METHODS FOR EXTENDED LIFETIME.
- AUTOMATED METHODS FOR INSTRUMENT PRIORITIZATION AND OPERATIONS SCHEDULING.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN

	FY 91	92	93	94	95
ASSEMBLY INSPECTION AND SERVICING	1.2	1.4	1.5	1.5	1.6
INTERFACE AND COMPATIBILITY	0.6	0.6	0.6	0.8	0.8
EXTENDED LIFE AND EFFICIENCY		0.2	0.4	0.4	0.4
AUTOMATED SCHEDULING AND PRIORITIZATION	0.3	0.4	0.5	0.5	0.6
$M TOTAL*	2.1M	2.6M	3.0M	3.2M	3.4M

*Does not include cost of flight hardware and flight

E. MADARAS

NDE Input for Robotic Servicing

SCOPE

DEVELOP THE ABILITY TO OBTAIN NDE SERVICE FOR CAUSE INFORMATION.

OBJECTIVE

- PROVIDE ROBOTIC NDE CAPABILITY FOR PRIORITIZATION OF SERVICING NEEDS AND REDUCE EVA REQUIREMENTS.

RATIONALE

- DEVELOP NDE CAPABILITIES THAT ARE COMPATIBLE WITH ROBOTICS TO IDENTIFY AND ASSESS PROBLEMS AND TO EVALUATE THEIR REPAIR.
- ALLOW FOR THE MONITORING OF MATERIAL CONDITIONS AND DEGRADATIONS SUCH AS INSPECTING THERMAL CONTROL COATINGS AND IMPACT DAMAGE WITHOUT EVA ACTIVITIES.

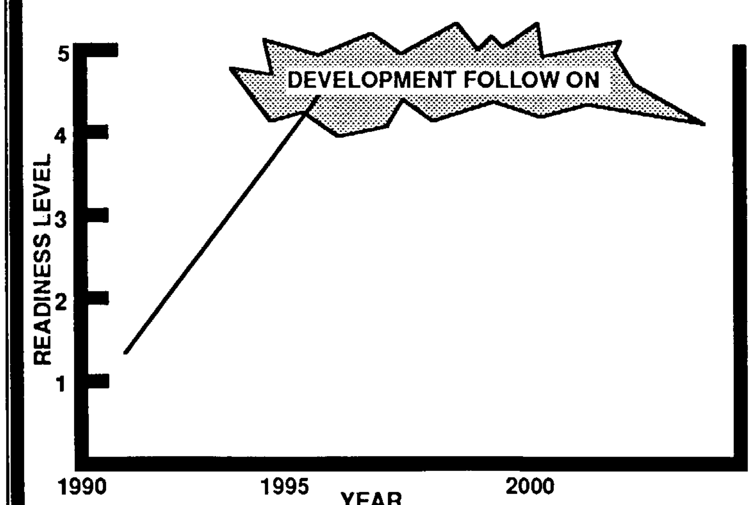
APPROACH

- DEVELOP METHODS FOR COUPLING ENERGY INTO MATERIALS AND STRUCTURES TO INTERROGATE THE SYSTEM, SUCH AS WITH NONCONTACTING OPTICAL OR THERMAL METHODS.
- INCORPORATE THESE METHODS INTO SYSTEMS THAT ARE ROBOT COMPATIBLE.

DELIVERABLES

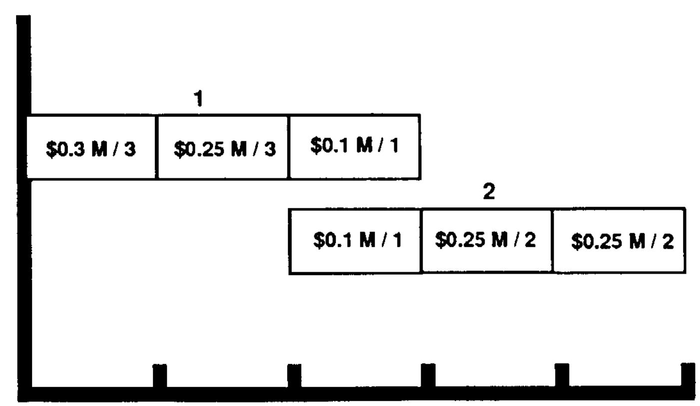
1. DEVELOP THERMAL AND OPTICAL SYSTEMS THAT CAN PERFORM NDE ON SPACE STRUCTURES WITHOUT REQUIRING COUPLANTS OR CONTACT AS IS THE CASE FOR EARTH-BASED NDE SYSTEMS.
2. DEVELOP PROTOTYPE SYSTEMS THAT CAN BE DEMONSTRATED WITH ROBOTICS.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



YR	1991	1992	1993	1994	1995	1996

$/MY	$0.3 M	$0.25 M	$0.2 M	$0.25 M	$0.25 M
	3	3	2	2	2

E. MADARAS

Fastener Recertification in Space

SCOPE

DEVELOP FASTENER CERTIFICATION AND RECERTIFICATION TECHNIQUES FOR SPACE-BASED NDE APPLICATIONS.

OBJECTIVE

- DEVELOP A MORE RELIABLE SYSTEM FOR MONITORING, CERTIFYING, OR RECERTIFYING FASTENERS.

RATIONALE

- NEED A SYSTEM TO IDENTIFY COUNTERFEIT FASTENERS.
- NEED A SYSTEM THAT CAN ACCURATELY MEASURE FASTENER LOADS, EVEN IN A SPACE-BASED ENVIRONMENT.

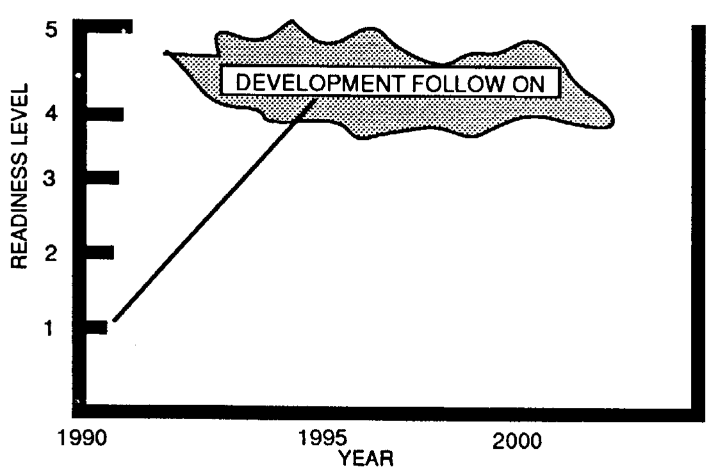
APPROACH

- DEVELOP METHODS SUCH AS ACOUSTOELASTIC AND THERMOELECTRIC FOR APPLICATION TO FASTENER QUALITY.
- DEVELOP AN ACCURATE METHOD TO EVALUATE THE LOADS ON CRITICAL FASTENERS.

DELIVERABLES

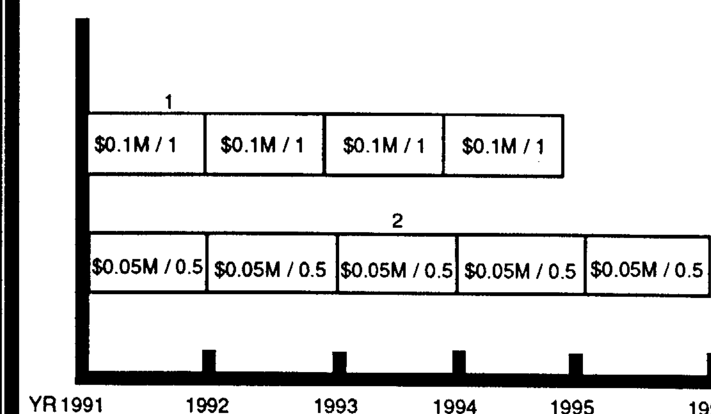
1. DEVELOP BOTH AN ACOUSTOELASTIC AND A THERMOELECTRIC SYSTEM FOR EVALUATING FASTENER QUALITY.
2. DEVELOP A PROTOTYPE PULSED PHASE LOCK LOOP SYSTEM THAT COULD BE USED IN SPACE AND WHICH COULD MEASURE CRITICAL FASTENER LOADS WITH HIGH ACCURACY FOR FASTENER CERTIFICATION OR RECERTIFICATION.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



YR	1991	1992	1993	1994	1995	1996
$/MY	$0.15 M 1.5	$0.15 M 1.5	$0.15 M 1.5	$0.15 M 1.5	$0.05 M 0.5	

Quantitative Surface Characterization Of Contaminants

E. MADARAS

SCOPE

DEVELOP QUANTITATIVE INSTRUMENTATION FOR DETECTION OF SURFACE CONTAMINANTS ON CRITICAL AND SENSITIVE COMPONENTS.

OBJECTIVE

- TO ENSURE CONTAMINATION SENSITIVE SURFACES ARE CLEAN.
- IDENTIFY CONTAMINANTS QUANTITATIVELY.

RATIONALE

- CONTAMINANTS REDUCE THE EFFICIENCY OF OPTICAL SYSTEMS
- CONTAMINANTS CAN BE THE SOURCE OF PLASM GENERATION AND ELECTRICAL DISCHARGES THAT INTERFERE OR DAMAGE SENSITIVE ELECTRONIC EQUIPMENT.

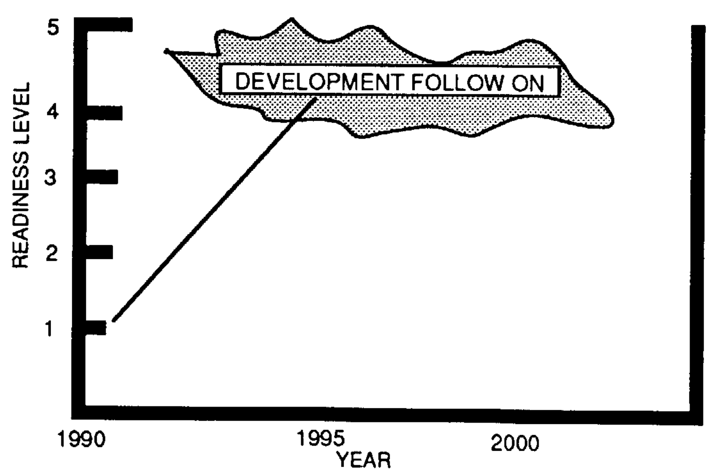
APPROACH

- DEVELOP A NARROW BAND FLUORESCENCE SYSTEM CAPABLE OF DETECTING MINUTE QUANTITIES OF CONTAMINANTS.
- EVALUATE THE SYSTEM ON A SERIES OF COMMON CONTAMINANTS THAT WILL DEFINE THE SYSTEM ACCURACY.
- EXPAND THE SYSTEM TO MULTIPLE BANDS FOR ACCURATE, QUANTITATIVE IDENTIFICATION OF CONTAMINANTS

DELIVERABLES

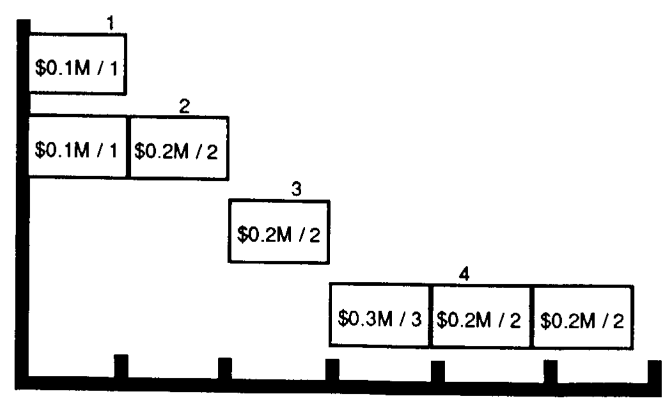
1. ASSESSMENT OF TECHNOLOGY FOR QUANTITATIVE SYSTEM.
2. INCORPORATE APPROPRIATE EXCITATION SYSTEMS.
3. EVALUATION OF NARROW BAND SYSTEM.
4. DEVELOP AND DEMONSTRATE A MULTIBAND SYSTEM.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



YR 1991	1992	1993	1994	1995	1996	1997
$/MY	$0.2 M	$0.2 M	$0.2 M	$0.3 M	$0.2 M	$0.2 M
	2	2	2	3	2	2

LaRC GCTI Spacecraft Technologies

2.4 Power

Technology	NASA GCTI WBS	Proposal funding requirements, millions of dollars					
		FY90	FY91	FY92	FY93	FY94	FY95
Electronics nondestructive evaluation (NDE)			0.2	0.25	0.2	0.25	0.25
Totals			0.2	0.25	0.2	0.25	0.25

E. MADARAS

Electronics NDE

SCOPE

DEVELOP ELECTRONICS NDE METHODS FOR CRITICAL ELECTRONIC ELEMENTS.

OBJECTIVE

- DEVELOP HIGHER RELIABILITY ELECTRONICS AND SYSTEMS.

RATIONALE

- INTRODUCE ELECTRONICS RELIABILITY RESEARCH INTO PROGRAM.
- WILL BUILD ON THE EXISTING ELECTRONICS NDE PROGRAM AT LANGLEY.
- WILL TAKE ADVANTAGE OF NEW LEAD NDE CENTER TECHNOLOGY IN ULTRASONICS, MAGNETICS, THERMAL, X-RAY, AND FIBER OPTICS.

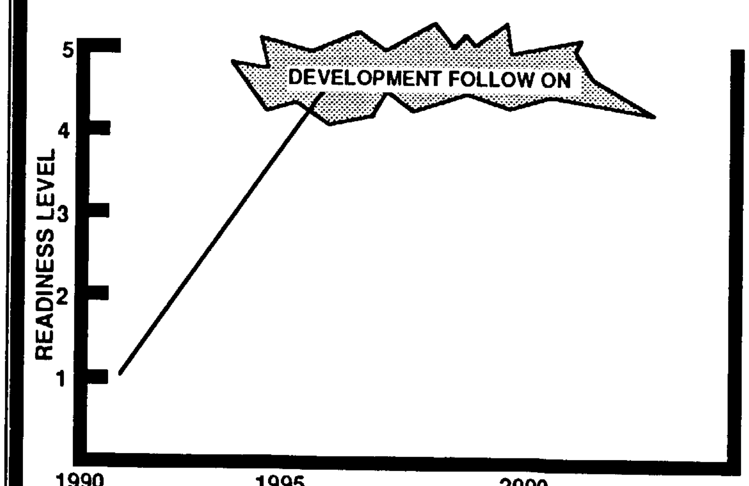
APPROACH

- TO EXTEND OUR CURRENT TECHNIQUES IN NDE (THERMAL WAVE ANALYSIS/TECHNOLOGY, BONDING, FATIGUE, PROCESS CONTROL MONITORS, AND INTEGRATED SENSORS) TO APPLICATIONS OF ELECTRONICS NDE.

DELIVERABLES

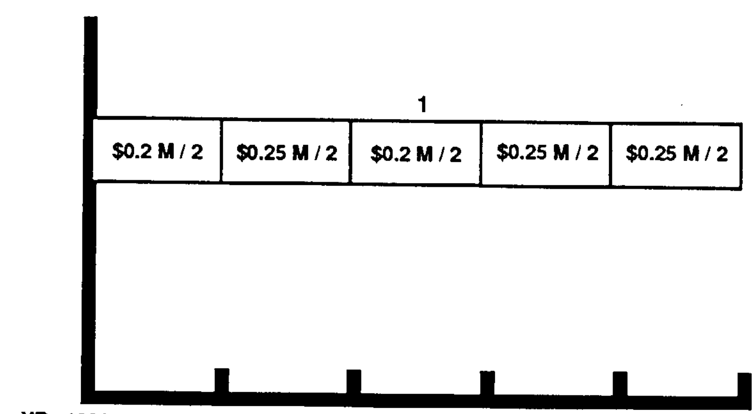
1. METHODS TO DETECT ELECTRONIC COMPONENT PROBLEMS AND PROVIDE FOR REAL-TIME MONITORS FOR ELECTRONICS NDE "HEALTH" MONITORING.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



YR	1991	1992	1993	1994	1995	1996
$/MY	$0.2 M 2	$0.25 M 2	$0.2 M 2	$0.25 M 2	$0.25 M 2	

LaRC GCTI Spacecraft Technologies

2.5 Propulsion

Technology	NASA GCTI WBS	Proposal funding requirements, millions of dollars					
		FY90	FY91	FY92	FY93	FY94	FY95
Thermal NDE for pressurized vessels			0.15	0.15	0.2	0.3	0.1
Weld inspection			0.2	0.15	0.15	0.15	0.1
Totals			0.35	0.3	0.35	0.45	0.2

E. MADARAS

Thermal NDE for Pressurized Vessels

SCOPE

DEVELOP AN IMPROVED THERMAL INSPECTION SYSTEM FOR PRESSURIZED VESSELS.

OBJECTIVE

- DEVELOP THE ABILITY TO INSPECT FOR STRESS DISTRIBUTIONS, CRACKS, AND LEAKS OVER LARGE AREAS AND UNDER LOAD.

RATIONALE

- REDUCE COST OF INSPECTION BY INSPECTING LARGE AREAS IN A SHORT PERIOD OF TIME.
- IMPROVE SAFETY AND RELIABILITY OF PROPULSION SYSTEMS.

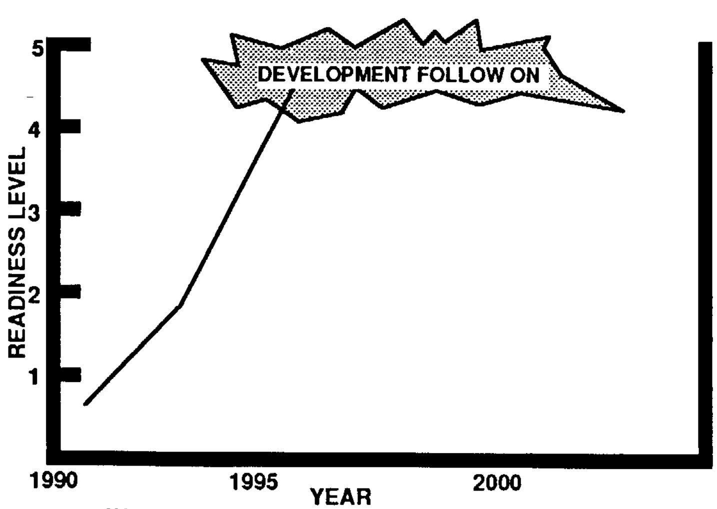
APPROACH

- DEVELOP A DATA BASE BETWEEN DEFECT TYPES AND MEASUREMENT RESOLUTION.
- IMPROVE HARDWARE AND SOFTWARE FOR FASTER INSPECTION SPEED WITH REDUCED COST.

DELIVERABLES

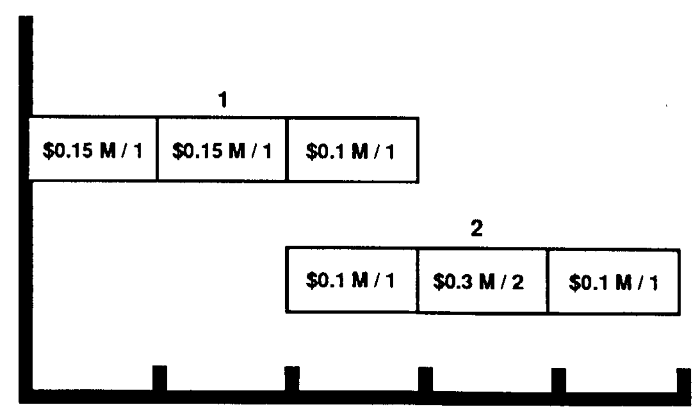
1. A DATA BASE ON THE ACCURACY AND RELIABILITY OF THE METHOD.
2. A PROTOTYPE SYSTEM THAT WILL HAVE IMPROVED SPEED.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



YR	1991	1992	1993	1994	1995	1996
$/MY	$0.15 M	$0.15 M	$0.2 M	$0.3 M	$0.1 M	
	1	1	2	2	1	

E. MADARAS

Weld Inspection of Pressurized Vessels

SCOPE
DEVELOP IMPROVED NDE INSPECTION SYSTEM FOR MICROCRACKS NEAR WELDS IN PRESSURIZED VESSELS.

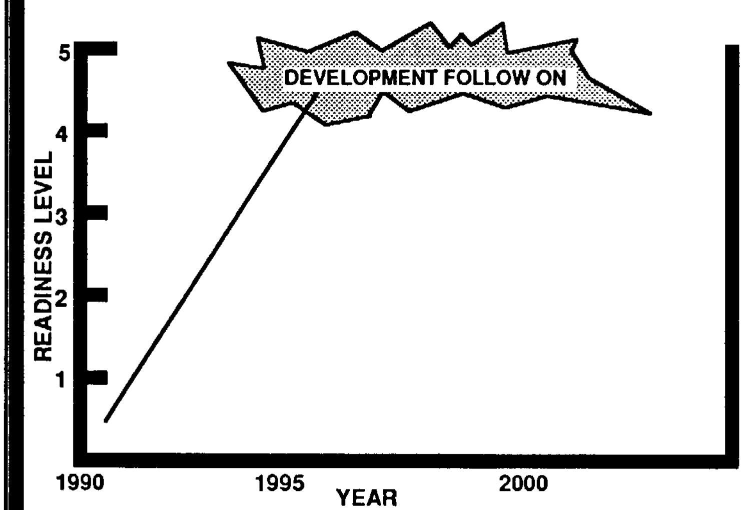
OBJECTIVE
- PROVIDE A PRACTICAL ABILITY TO INSPECT WELD INTEGRITY, NEARBY STRESS DISTRIBUTIONS, AND HYDROGEN-RELATED METAL PROBLEMS.

RATIONALE
- NO SINGLE NDE TECHNIQUE HAS BEEN SUCCESSFUL IN EVALUATING WELD DEFECTS IN PRACTICAL MEASUREMENT SYSTEMS.
- PROVIDE A QUANTITATIVE ASSESSMENT OF MECHANICAL PROPERTIES OF CRITICAL PARTS.
- ENHANCE SAFETY AND RELIABILITY OF PROPULSION SYSTEMS.

APPROACH
- DEVELOP A SYSTEM THAT CAN INSPECT FOR MICROCRACKS AND OTHER WELDMENT PROBLEMS.

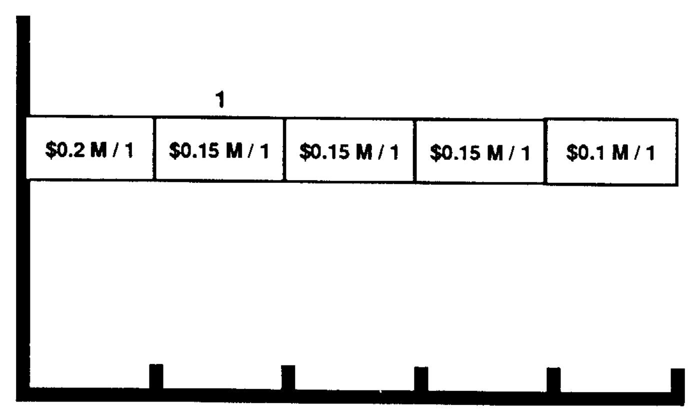
DELIVERABLES
1. A PROTOTYPE SYSTEM THAT WILL HAVE THE CAPABILITY TO INSPECT FOR WELD INTEGRITY.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



YR	1991	1992	1993	1994	1995	1996
$/MY	$0.2 M	$0.15 M	$0.15 M	$0.15 M	$0.1 M	
	1	1	1	1	1	

LaRC GCTI Spacecraft Technologies

2.6 Thermal Control

Technology	NASA GCTI WBS	Proposal funding requirements, millions of dollars					
		FY90	FY91	FY92	FY93	FY94	FY95
NDE for thermal control			0.2	0.2	0.3	0.3	0.3
Thermoelastic NDE			0.15	0.15	0.2	0.3	0.1
Totals			0.35	0.35	0.5	0.6	0.4

NDE For Thermal Control Systems

E. MADARAS

SCOPE

DEVELOP ADVANCED OPTICAL METHODS FOR TESTING THERMAL SYSTEMS.

OBJECTIVE

- ENABLE ACCURATE EVALUATION OF STRESSES IN THERMAL CONTROL SYSTEMS.

RATIONALE

- TECHNOLOGY WILL PROVIDE HIGH RESOLUTION STRESS MAPS OF SURFACES.
- PROVIDE NONCONTACTING METHOD TO MONITOR STRUCTURAL IRREGULARITIES AND DISTORTIONS.

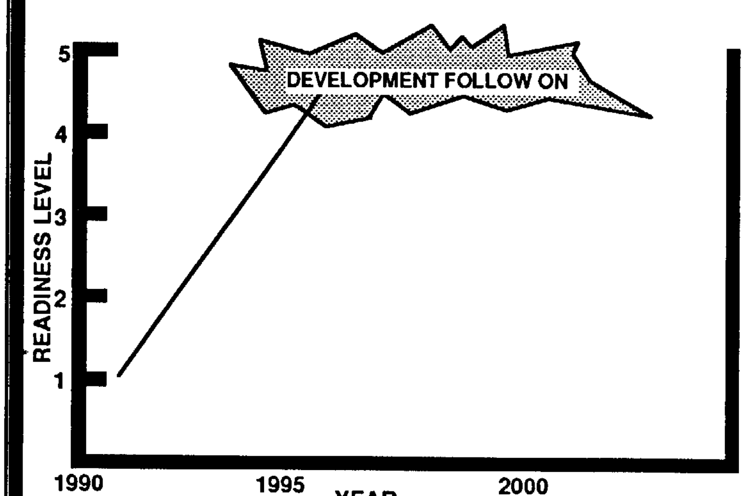
APPROACH

- ACQUIRE LASERS AND DETECTORS WITH HIGH BANDWIDTHS.
- DEVELOP REAL-TIME IMAGE ANALYSIS ALGORITHMS FOR STRESS MAPS.

DELIVERABLES

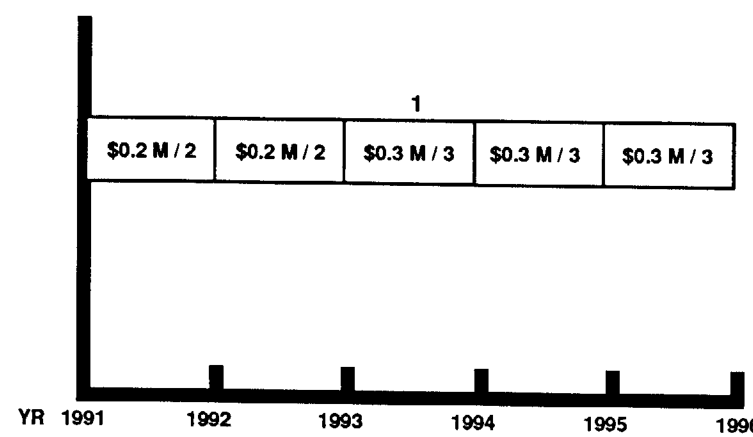
1. A NONCONTACTING METHOD TO DETECT STRESS MAPS OF SURFACES WITH HIGH RESOLUTION IN A REASONABLE AMOUNT OF TIME AND TO MAP OUT STRUCTURAL IRREGULARITIES OF THERMAL CONTROL SYSTEMS.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



$/MY					
	$0.2 M	$0.2 M	$0.3 M	$0.3 M	$0.3 M
	2	2	3	3	3

E. MADARAS

Thermoelastic NDE For Thermal Control Systems

SCOPE

DEVELOP FAST THERMOELASTIC INSPECTION SYSTEM.

OBJECTIVE

- THE DETECTION OF DEFECTS LOCATED IN JOINTS AND BONDS.

RATIONALE

- REDUCE COST OF INSPECTION BY INSPECTING LARGE AREAS IN A SHORT PERIOD OF TIME.
- IMPROVE SAFETY AND RELIABILITY OF THERMAL SYSTEMS.

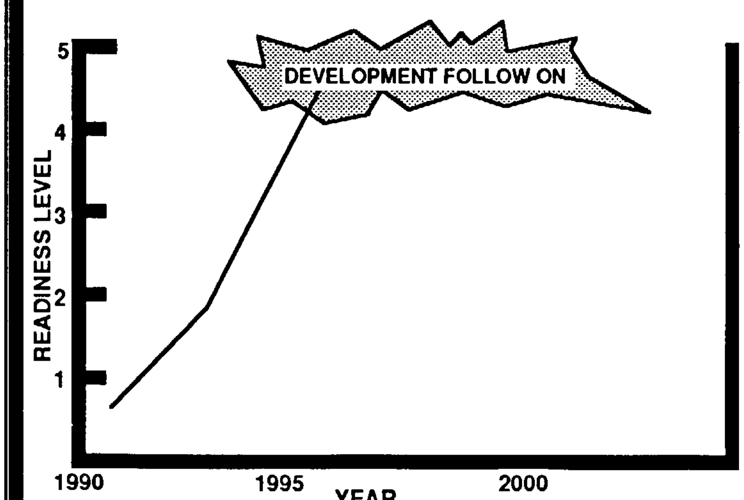
APPROACH

- DEVELOP A DATA BASE BETWEEN DEFECT TYPES AND MATERIALS MEASUREMENTS.
- IMPROVE HARDWARE AND SOFTWARE FOR FASTER INSPECTION SPEED WITH REDUCED COST.

DELIVERABLES

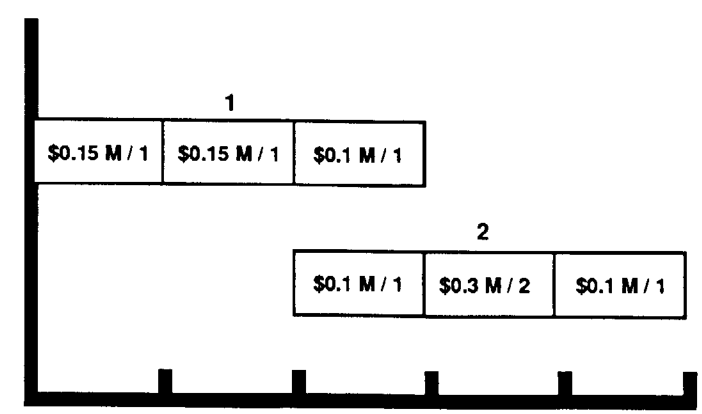
1. A DATA BASE ON THE ACCURACY AND RELIABILITY OF THE METHOD.
2. A PROTOTYPE SYSTEM THAT WILL HAVE IMPROVED SPEED.

TECHNOLOGY ASSESSMENT



WORKING AT READINESS LEVELS OF 2 THROUGH 5

DEVELOPMENT PLAN



YR	1991	1992	1993	1994	1995	1996
$/MY	$0.15 M	$0.15 M	$0.2 M	$0.3 M	$0.1 M	
	1	1	2	2	1	

Appendix C
Data and Information Systems Technology Proposals (WBS 3.0)

LaRC GCTI Information Technologies

3.1 Systems

Technology	NASA GCTI WBS	Proposal funding requirements, millions of dollars					
		FY90	FY91	FY92	FY93	FY94	FY95
Tool development and integration	3.11–2		0.45	0.65	0.95	0.6	0.2
Architectures	3.11–1		0.8	1.5	1.0	0.5	
Software engineering	3.12–4		1.0	1.3	2.0	1.5	1.0
Dependable software	3.12–5		0.7	1.1	1.2	1.1	0.8
Software library and reuse	3.12–3		0.5	1.0	1.0	1.0	1.0
Automated parallel software	3.12–1		0.5	1.0	2.0	1.0	0.5
			3.95	6.55	8.15	5.7	3.5

W. BRYANT

DATA SYSTEMS DESIGN & EVALUATION
TOOL DEVELOPMENT & INTEGRATION

SCOPE

INTEGRATE DESIGN TOOLS IN AN ENVIRONMENT TO SUPPORT AN EFFECTIVE DESIGN METHOD.

OBJECTIVES

- IDENTIFY / REFINE METHODOLOGY FOR EFFECTIVE DATA SYSTEM DESIGN.
- DETERMINE EXISTING / NEEDED TOOLS TO SUPPORT METHODOLOGY.
- INTEGRATE TOOLS INTO COMMON ENVIRONMENT TO SUPPORT METHOD.

RATIONALE

EXISTING COMPUTER-AIDED DESIGN/COMPUTER-AIDED ENGINEERING (CAD/CAE) DESIGN TOOLS ARE NOT COMPATIBLE WITH EACH OTHER, NOR DO THEY COLLECTIVELY ADDRESS ALL COMPUTING SYSTEMS DESIGN PHASES

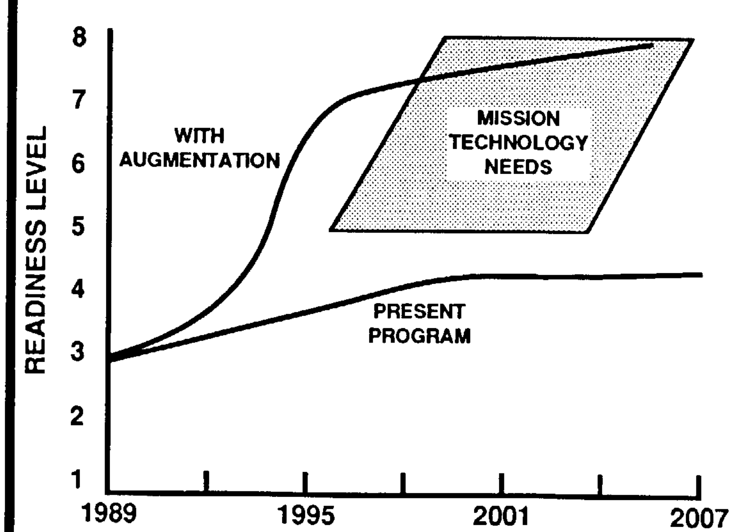
APPROACH

USE AN EXISTING DESIGN METHODOLOGY ON GCTI APPLICATION TO IDENTIFY EXISTING / NEEDED TOOLS TO SUPPORT METHOD. DEVELOP NEW TOOLS AND INTEGRATE WITH EXISTING ONES.

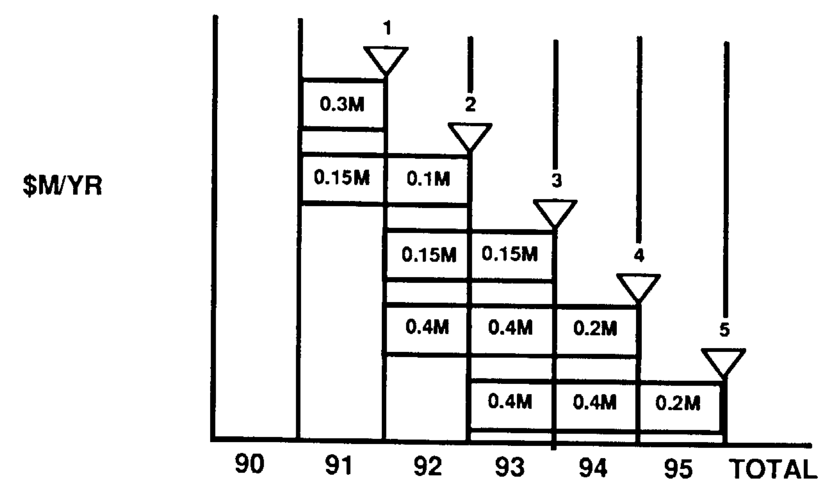
DELIVERABLES

1. ENHANCED DESIGN METHOD FOR GCTI DATA SYSTEMS.
2. IDENTIFY APPLICABLE EXISTING TOOLS.
3. GENERATE REQUIREMENTS FOR NEW TOOLS.
4. BUILD NEW TOOLS IDENTIFIED IN 3.
5. INTEGRATED TOOL SET SUPPORTING METHOD.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



	90	91	92	93	94	95	TOTAL
TOTAL $M/YR		0.45	0.65	0.95	0.6	0.2	2.85

N. MURRAY

GLOBAL DISTRIBUTED COMPUTING ARCHITECTURES

SCOPE
RESEARCH AND DEVELOP THE ARCHITECTURAL CONCEPT FOR ONBOARD PROCESSING ACROSS MULTIPLE OBSERVATION SPACECRAFT.

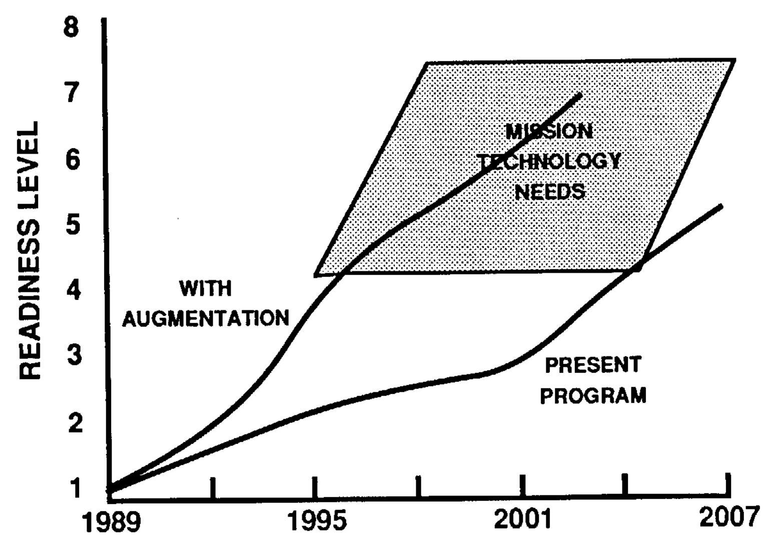
OBJECTIVES
- ASSESS GLOBAL SATELLITE SCIENCE REQUIREMENTS AND ALGORITHMS FOR ONBOARD PROCESSING.
- CREATE SIMULATION CAPABILITY TO EVALUATE ALGORITHMS AND ARCHITECTURES.
- EVALUATE ARCHITECTURES / ALGORITHMS - RECOMMEND ARCHITECTURE CONCEPT.

RATIONALE
ENABLE SCIENCE USERS DIRECT ACCESS TO SENSOR DATA AND GLOBAL INFORMATION.

APPROACH
USE EXISTING SIMULATIVE PROGRAMS AND AUGMENT WHERE NECESSARY: CREATE AND EVALUATE NEW, INNOVATIVE, AND ORIGINAL ARCHITECTURAL CONCEPTS TO MEET UNIQUE NASA REQUIREMENTS.

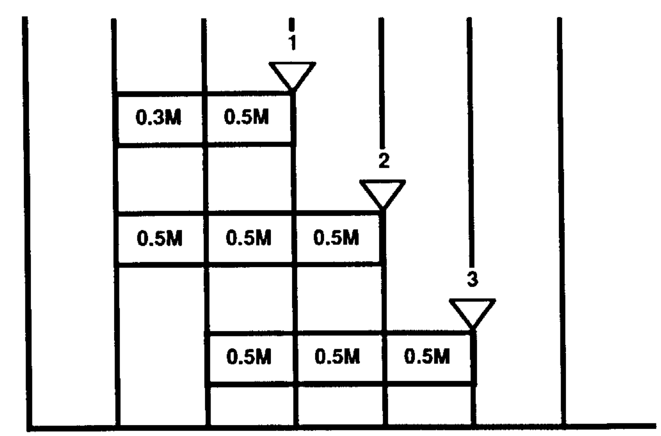
DELIVERABLES
1. ASSESS SCIENCE REQUIREMENTS AND ALGORITHMS.
2. CREATE EMULATIVE / SIMULATIVE ABILITY.
3. ARCHITECTURAL CONCEPT EVALUATIONS.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN

$M/YR



	90	91	92	93	94	95	TOTAL
TOTAL $M/YR		0.8	1.5	1.0	0.5		3.8

SOFTWARE ENGINEERING ENVIRONMENT FOR GCTI

C. WALKER

SCOPE
PROVIDE AN INTEGRATED SET OF TOOLS FOR THE DEVELOPMENT OF GLOBAL CHANGE APPLICATION SOFTWARE THROUGHOUT THE LIFE CYCLE.

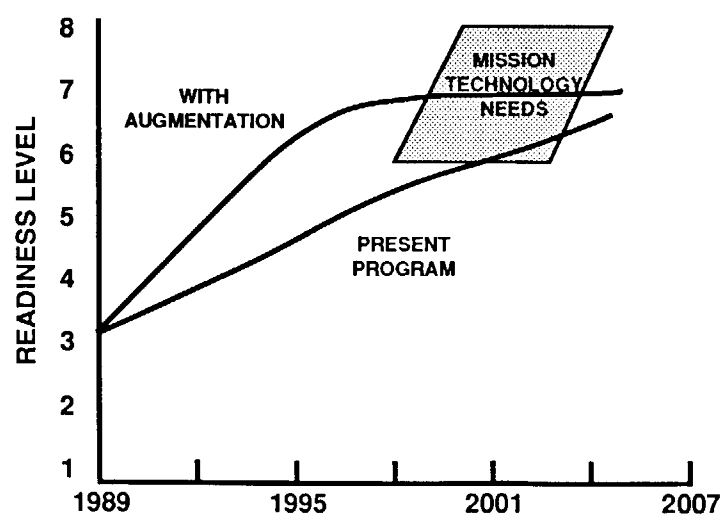
OBJECTIVES
- INTEGRATION OF AUTOMATED DEVELOPMENT TECHNIQUES AND REUSABLE LIBRARY.
- AUTOMATED PROJECT AND CONFIGURATION MANAGEMENT.
- EFFICIENT AND TRACEABLE MAINTENANCE.

RATIONALE
REDUCED LIFE-CYCLE COSTS AND INCREASED SOFTWARE QUALITY THROUGH AUTOMATED DEVELOPMENT AND MAINTENANCE.

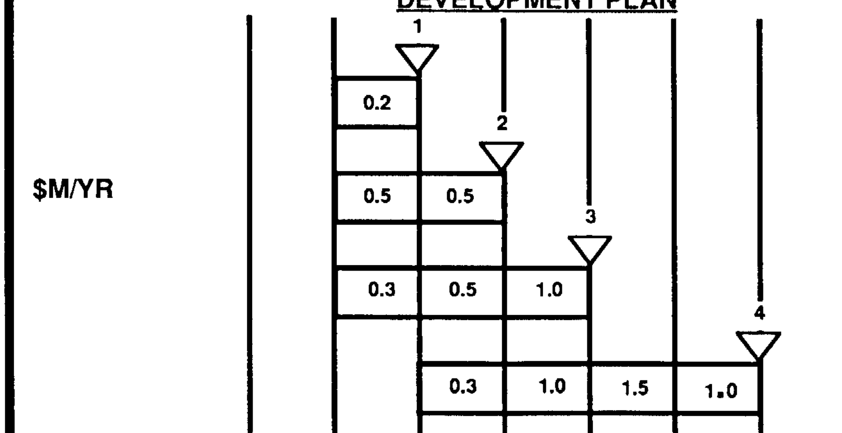
APPROACH
DEVELOP EMERGING TECHNOLOGIES SUCH AS REUSABILITY AND AUTOMATED PROGRAMMING.
COMBINE WITH AUTOMATED SPECIFICATION AND ANALYSIS TECHNIQUES AND PROVIDE PROJECT MANAGEMENT CAPABILITIES TO PRODUCE AN INTEGRATED SOFTWARE ENVIRONMENT.

DELIVERABLES
1. NEEDED TOOLS / CAPABILITIES IDENTIFIED.
2. SPECIFICATION AND ANALYSIS TOOLS.
3. AUTOMATED SPECIFICATION AND PROGRAMMING SUBSYSTEM.
4. INTEGRATED LIBRARY / PROGRAMMING SYSTEM.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



	90	91	92	93	94	95	TOTAL
TOTAL $M/YR		1.0	1.3	2.0	1.5	1.0	6.8
TOTAL MY/YR		3.0	3.0	4.0	4.0	3.0	17.0

DEPENDABLE SOFTWARE

S. VOIGT

SCOPE

DEVELOP AND INTEGRATE TECHNOLOGIES NEEDED TO PRODUCE SOFTWARE THAT IS CORRECT, ROBUST, SAFE, AND FAULT TOLERANT.

OBJECTIVES

- IDENTIFY EFFECTIVE FAULT AVOIDANCE METHODS FOR SOFTWARE DEVELOPMENT.
- DEVELOP AND VALIDATE RELIABILITY AND SAFETY ANALYSIS TECHNIQUES.
- DEVELOP AUTOMATED TESTING METHODS.

RATIONALE

INCREASED SOFTWARE DEPENDABILITY THROUGH QUALITY DESIGN, ANALYSIS, AND AUTOMATED TESTING.

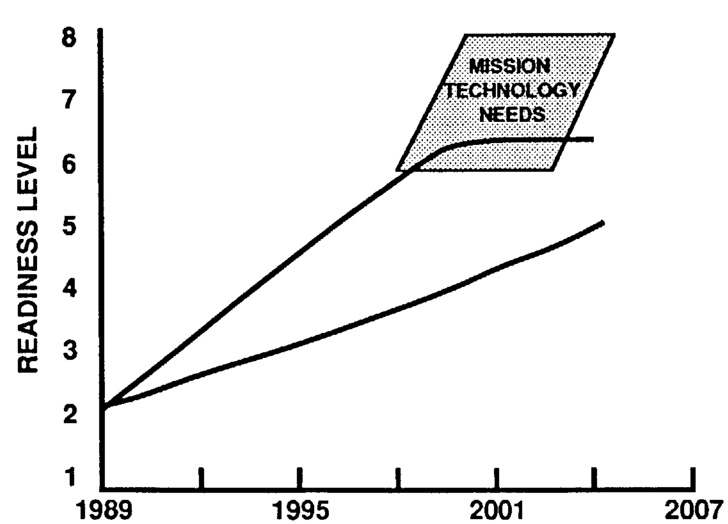
APPROACH

DEVELOP AND ASSESS TECHNOLOGY IN THE AREAS OF FAULT AVOIDANCE, FAULT ELIMINATION, FAULT TOLERANCE, RELIABILITY ANALYSIS, SAFETY TECHNIQUES, AND AUTOMATED TESTING METHODS FOR USE IN DEVELOPMENT OF GLOBAL CHANGE APPLICATION SOFTWARE.

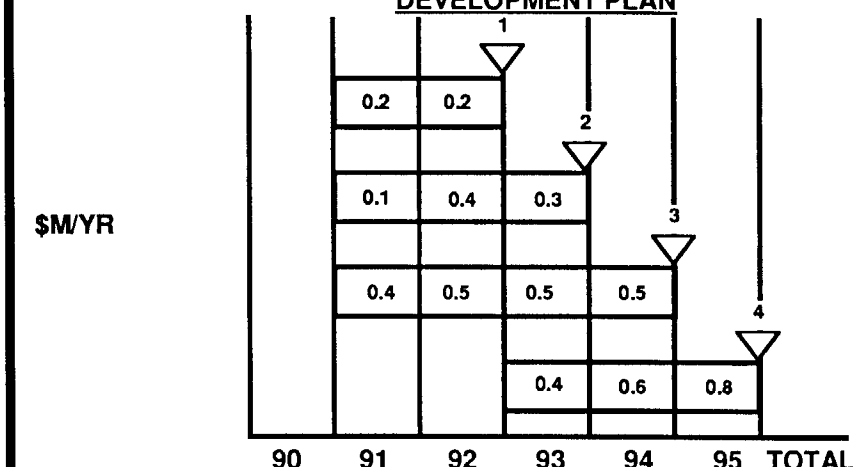
DELIVERABLES

1. DEPENDABLE SOFTWARE DEVELOPMENT GUIDELINES.
2. AUTOMATED TESTING METHODOLOGY.
3. RELIABILITY AND SAFETY ANALYSIS TOOL.
4. SUITE OF TESTING TOOLS.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



	90	91	92	93	94	95	TOTAL
TOTAL $M/YR		0.7	1.1	1.2	1.1	0.8	4.9
TOTAL MY/YR		3.0	3.5	4.0	4.0	2.0	16.5

S. VOIGT

SOFTWARE LIBRARY AND REUSE

SCOPE
ROBUST REUSABLE SOFTWARE ELEMENTS AND SUITABLE LIBRARY SUPPORT MECHANISMS FOR GLOBAL CHANGE APPLICATIONS.

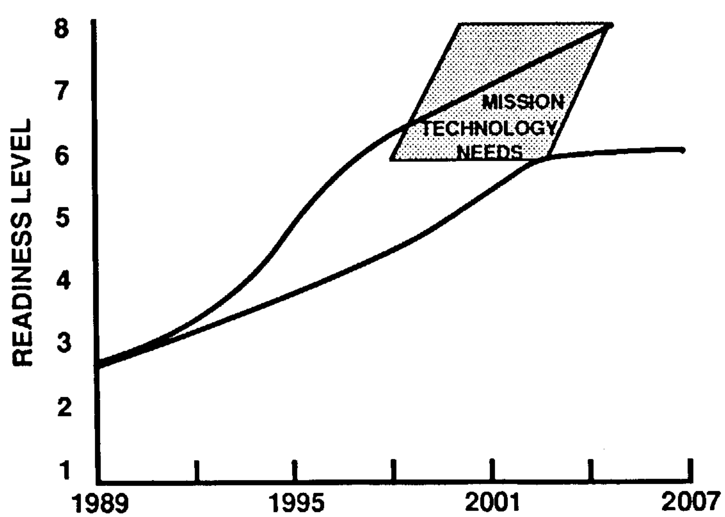
OBJECTIVES
- DEVELOP METHODOLOGY FOR CREATING AND USING PLUG-COMPATIBLE SOFTWARE PARTS.
- CREATE LIBRARY MECHANISM TO SUPPORT REUSABLE PARTS SUITABLE FOR GLOBAL CHANGE APPLICATIONS.
- DEVELOP GUIDELINES FOR SOFTWARE REUSE THROUGHOUT THE SOFTWARE LIFE CYCLE.

RATIONALE
GREATER PRODUCTIVITY AND QUALITY THROUGH REUSE OF ROBUST SOFTWARE ELEMENTS.

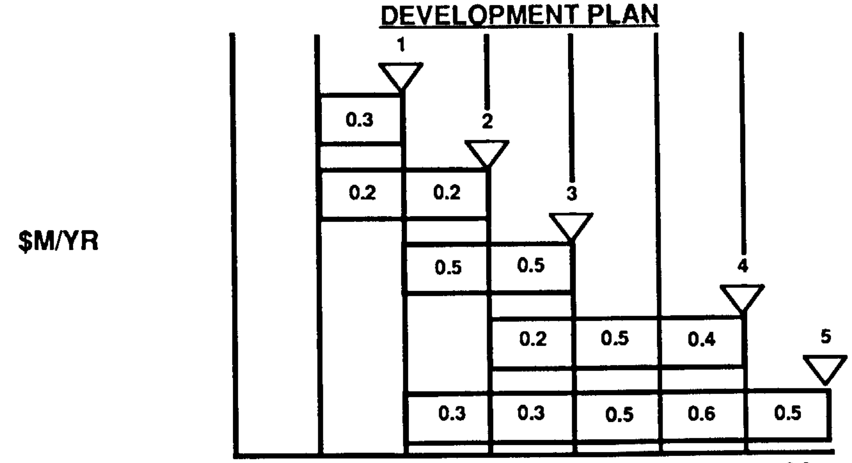
APPROACH
EVALUATE / IMPROVE REUSABLE SOFTWARE SYNTHESIS SYSTEM.
EXPLORE OBJECT-ORIENTED DESIGN AS A METHOD TO SUPPORT SOFTWARE REUSE.
PERFORM GLOBAL CHANGE DOMAIN ANALYSIS.
IDENTIFY AND ADAPT EXISTING SOFTWARE FOR GLOBAL CHANGE REUSE LIBRARY.

DELIVERABLES
1. INITIAL LIBRARY SYSTEM.
2. DOMAIN ANALYSIS OF GLOBAL CHANGE APPLICATIONS.
3. GUIDELINES FOR SOFTWARE REUSE.
4. REUSABLE GLOBAL CHANGE APPLICATION LIBRARY COMPONENTS.
5. EXPANDED LIBRARY SYSTEM FOR GLOBAL CHANGE APPLICATIONS.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



	90	91	92	93	94	95	96
TOTAL $M/YR		0.5	1.0	1.0	1.0	1.0	0.5
TOTAL MY/YR		2.0	3.0	3.0	3.0	2.0	1.0

C. WALKER

AUTOMATED PARALLEL SOFTWARE

SCOPE
DEVELOP THE CAPABILITY TO PRODUCE FROM A GRAPHICAL REPRESENTATION, ADA SOURCE CODE FOR PARALLEL EXECUTION.

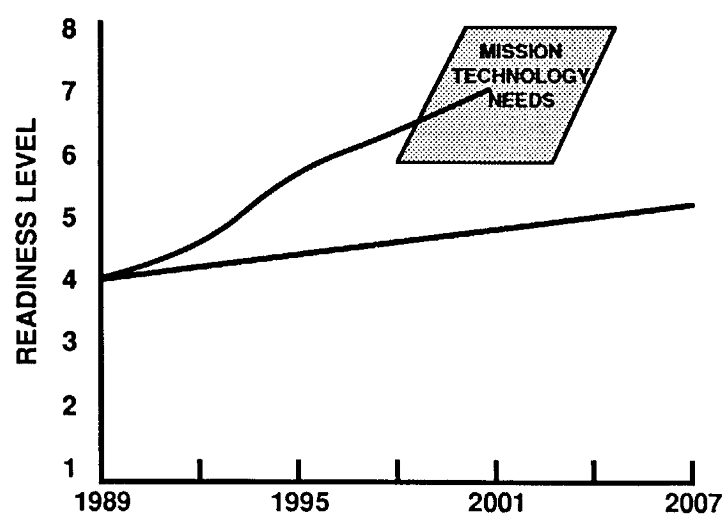
OBJECTIVES
- DEFINE SOFTWARE SPECIFICATIONS CLEARLY AND UNAMBIGUOUSLY.
- TRANSLATE SPECIFICATIONS TO PARALLEL CODE EASILY AND CORRECTLY.
- TEST AND MAINTAIN CODE EFFECTIVELY.

RATIONALE
ENABLE EFFECTIVE USE OF ADVANCED PARALLEL ARCHITECTURES NEEDED FOR COMPLEX ON-BOARD PROCESSING.

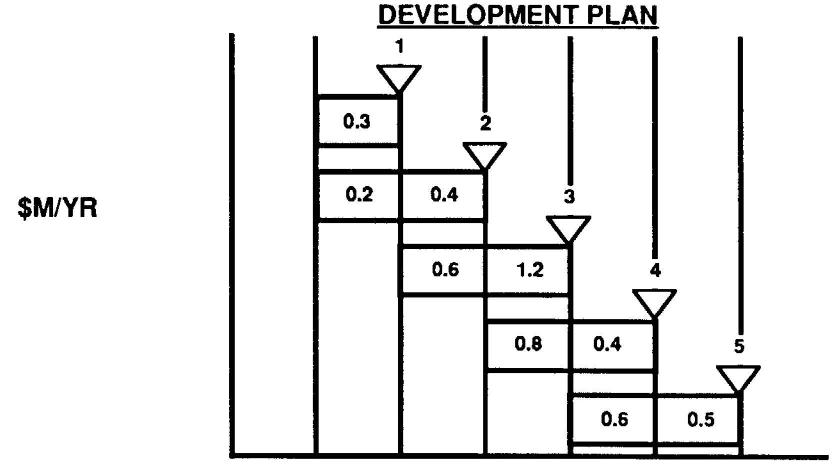
APPROACH
EXTEND CURRENT AND DEVELOPING AUTOMATED PROGRAMMING CAPABILITIES TO PROVIDE AUTOMATIC DISTRIBUTION OF ALGORITHMS AMONG MULTIPROCESSORS VIA SEQUENTIAL, GRAPHICAL SPECIFICATION OF SOFTWARE.

DELIVERABLES
1. AUTOMATED SEQUENTIAL PROGRAMMING TOOL.
2. AUTOMATIC TESTING / MANAGEMENT FACILITY.
3. PROTOTYPE PARALLEL CODE SYSTEM.
4. TESTING / MANAGEMENT FOR PARALLEL SOFTWARE.
5. AUTOMATIC PARALLEL SOFTWARE SYSTEM.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



	90	91	92	93	94	95	TOTAL
TOTAL $M/YR		0.5	1.0	2.0	1.0	0.5	5.0
TOTAL MY/YR		2.0	3.0	4.0	3.5	2.0	14.5

LaRC GCTI Information Technologies

3.2 Flight Element

Technology	NASA GCTI WBS	Proposal funding requirements, millions of dollars					
		FY90	FY91	FY92	FY93	FY94	FY95
Digital signal processor	3.21–2		1.5	2.0	4.0	4.0	
Application-specific integrated circuits			0.8	4.0	4.5	1.5	1.5
Chip-level integration	3.21–1		2.0	3.0	3.0	3.0	3.0
Low power GaAs preprocessors			0.4	0.6	1.0	1.0	0.5
Multiprocessors for sensor fusion	3.22–5		1.0	1.0	1.5	1.5	1.0
Spaceborne 32-bit RISC			7.0	7.0	7.0	7.0	7.0
16-bit VHSIC 1750A			1.5	1.0	0.8		
32-bit VHSIC 1750A			2.0	1.0	0.8		
High performance laser for optical recording	3.22–1	0.2	0.5	0.5	0.5	0.5	0.5
Photonic network	3.22–2		0.6	1.0	1.0	1.0	0.5
Spaceflight optical disk recorder	3.22–1		3.3	4.0	5.0	4.0	3.0
Integrated data processor		0.2	0.7	0.7	0.8	1.0	0.1
Sensor specific preprocessing			6.0	8.0	16.0	16.0	6.0
Totals		0.4	27.3	33.8	45.9	40.5	23.1

DIGITAL SIGNAL PROCESSOR

SCOPE
DEVELOP DIGITAL SIGNAL PROCESSING TECHNOLOGY FOR ONBOARD ADVANCED DATA PROCESSING FOR REMOTE SENSING INSTRUMENTS.

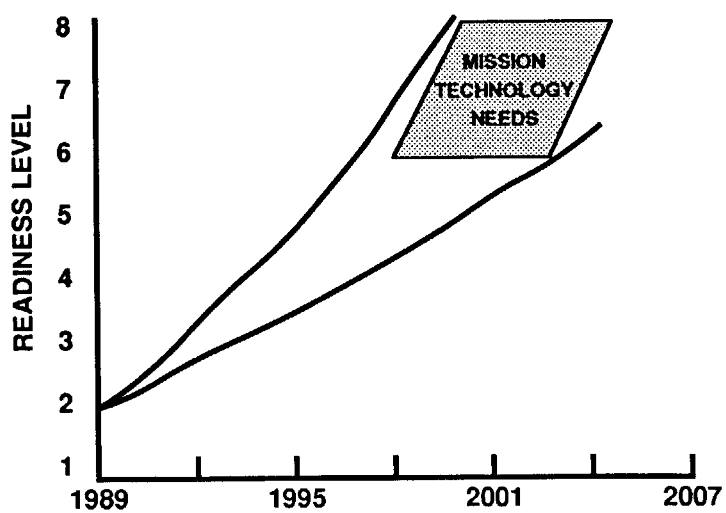
OBJECTIVES
- DEVELOP SPECIAL PURPOSE DIGITAL PREPROCESSING ALGORITHMS.
- FLIGHT QUALIFY SPECIAL PURPOSE DSP PROCESSORS.
- DEVELOP AND DEMONSTRATE DSP SYSTEM ARCHITECTURES.

RATIONALE
ENABLE DEVELOPMENT OF REAL-TIME HIGH RATE ADAPTIVE SENSORS THAT PERFORM ONBOARD PROCESSING AND CONTROL.

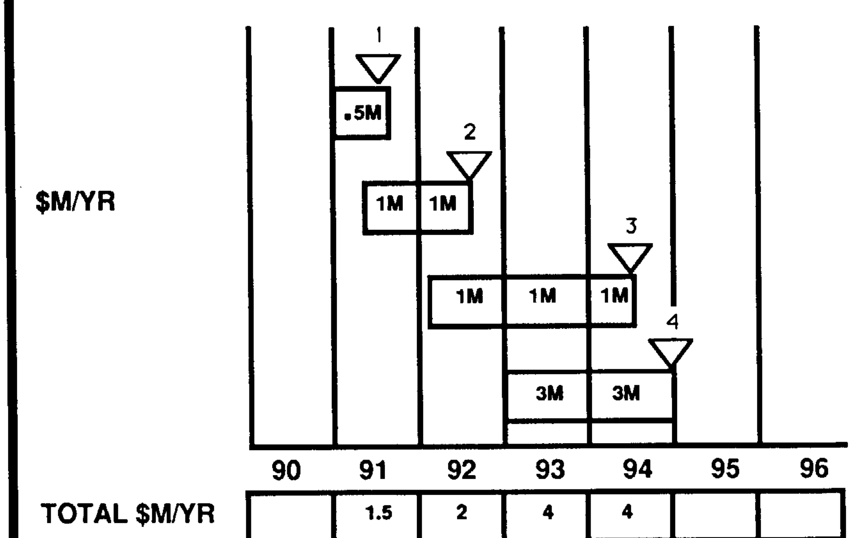
APPROACH
- ANALYZE GCTI INSTRUMENTS AND IDENTIFY TARGET FOR APPLICATION.
- ANALYZE TARGET AND DEVELOP ALGORITHM TO ACHIEVE REQUIRED PERFORMANCE.
- DEVELOP AND IMPLEMENT ALGORITHM USING COMMERCIALLY AVAILABLE DSP PROCESSORS.
- INCORPORATE IN TARGET APPLICATION BREADBOARD.
- SPACE-FLIGHT QUALIFY DSP PROCESSOR.

DELIVERABLES
1. SELECTED APPLICATION
2. ALGORITHMS AND DESIGN
3. BREADBOARD SYSTEM DEMONSTRATION
4. FLIGHT SYSTEM

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



S. JURCZYK

APPLICATION-SPECIFIC INTEGRATED CIRCUITS

SCOPE

DEVELOP AGENCY-WIDE CAPABILITY TO DESIGN, SIMULATE, AND TEST ASIC'S FOR HIGH-RATE SPACEFLIGHT DATA PROCESSING APPLICATIONS.

OBJECTIVES

- INCORPORATE ASIC'S INTO SPACEFLIGHT SYSTEMS.
- DEVELOP NASA-WIDE SYSTEM TO PERFORM DESIGN AND SIMULATION.
- ESTABLISH SPACEFLIGHT-QUALIFIED PROCESSES AND SOURCES.

RATIONALE

MAKE ASIC TECHNOLOGY READILY AVAILABLE FOR INCORPORATION INTO FUTURE SPACEFLIGHT SYSTEMS. ASIC'S WILL IMPROVE SYSTEM PERFORMANCE AND RELIABILITY USING LESS WEIGHT AND POWER.

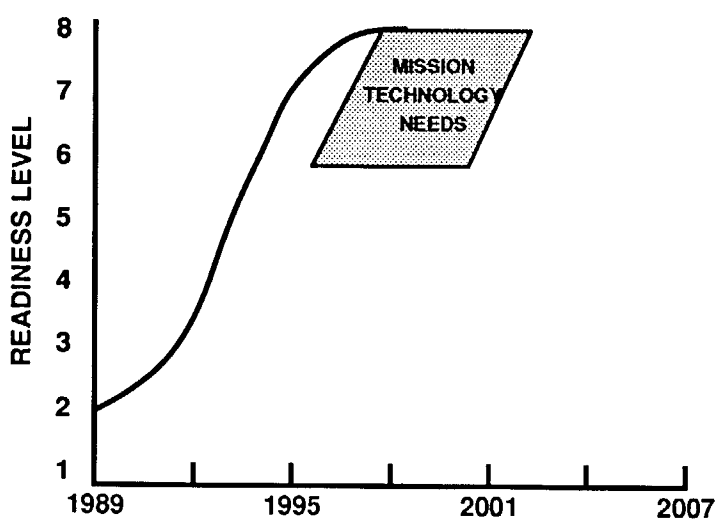
APPROACH

- DETERMINE CURRENT CAPABILITY AND FUTURE NEEDS.
- DEVELOP PLAN TO ESTABLISH INTEGRATED CAPABILITY.
- IMPLEMENT PLAN AND TARGET POTENTIAL APPLICATION.
- DESIGN, DEVELOP, AND DEMONSTRATE SPACEFLIGHT QUALIFIED ASIC.

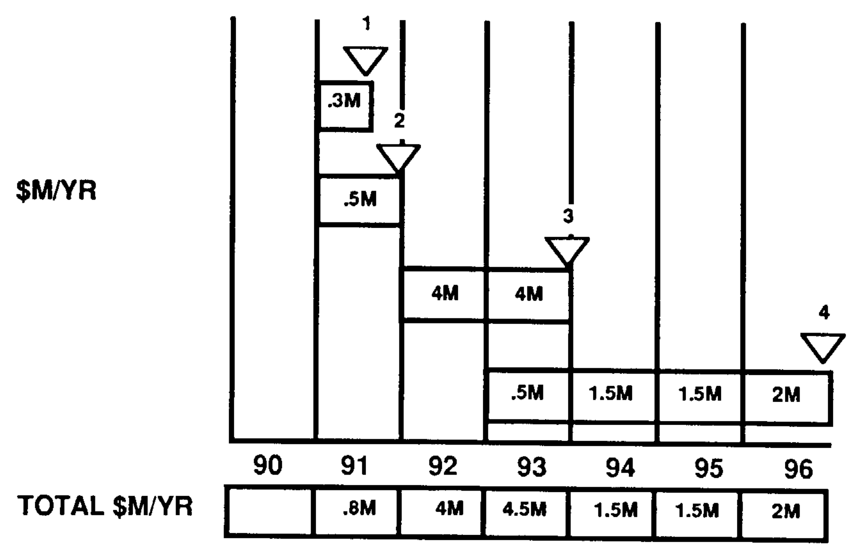
DELIVERABLES

1. CURRENT CAPABILITY AND NEED SURVEY
2. INTEGRATED CAPABILITY PLAN
3. SYSTEM TO DESIGN, SIMULATE, AND TEST ASIC'S
4. SPACEFLIGHT-QUALIFIED ASIC FUNCTIONING IN SYSTEM

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



S. JURCZYK

CHIP-LEVEL INTEGRATION

SCOPE
DEVELOP ENHANCED DETECTOR MODULES WITH INTEGRATED (ON-CHIP) PREPROCESSING ELEMENTS FOR ONBOARD IMAGE AND SPECTRAL DATA EXTRACTION.

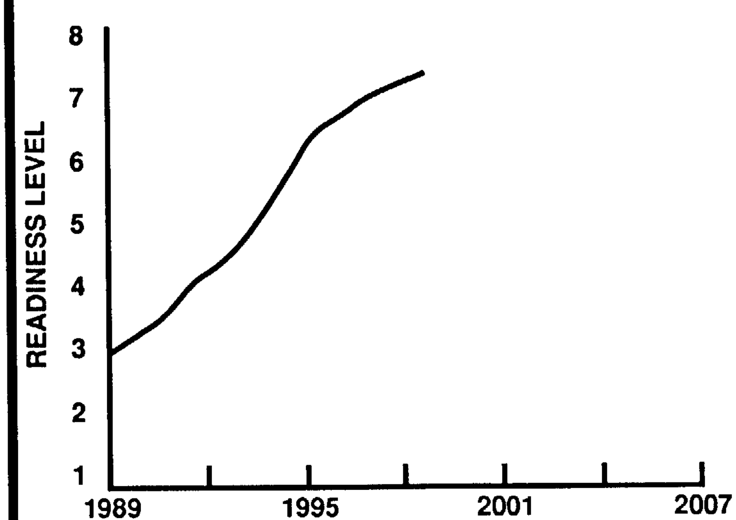
OBJECTIVES
- IMPROVE SYSTEM PERFORMANCE .
- IMPROVE RELIABILITY FOR LONG-LIFE SENSING.
- DECREASE SYSTEM POWER CONSUMPTION.

RATIONALE
MAXIMIZE PERFORMANCE OF EXISTING AND EMERGING DETECTOR TECHNOLOGIES FOR SPACEFLIGHT REMOTE SENSING SYSTEMS. ENHANCED DETECTOR MODULES WILL BE REQUIRED TO MEET POWER, WEIGHT, AND VOLUME CONSTRAINTS.

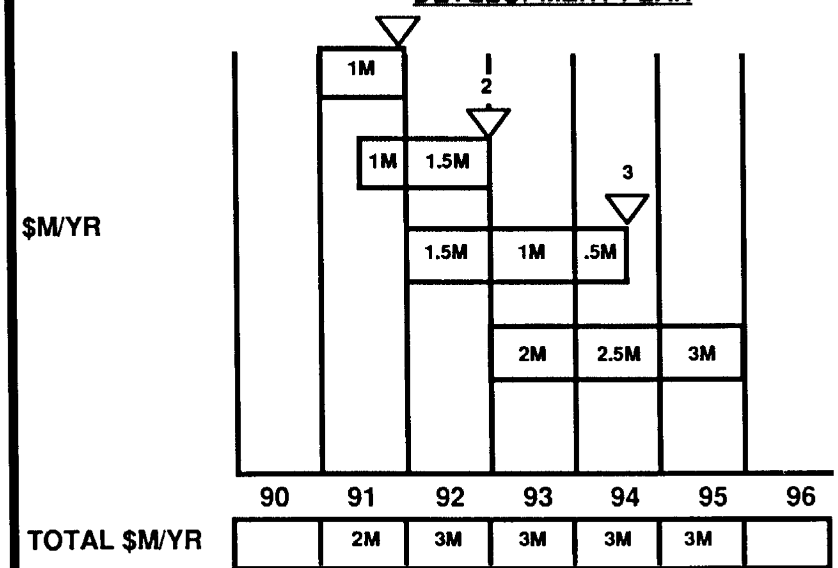
APPROACH
- ANALYZE GCTI INSTRUMENTS AND IDENTIFY TARGET FOR APPLICATION.
- ANALYZE, TARGET, AND DEVELOP ENHANCED SENSORS TO ACHIEVE IMPROVED PERFORMANCE.
- DESIGN AND BUILD ENHANCED DETECTORS USING COMMERCIALLY AVAILABLE HARDWARE.
- INTEGRATE DETECTOR IN TARGET BREADBOARD.
- BUILD AND QUALIFY SPACEFLIGHT-ENHANCED DETECTORS.

DELIVERABLES
1. REPORT ON SELECTED APPLICATION
2. DETECTOR MODULE DESIGN
3. BREADBOARD SYSTEM
4. FLIGHT SYSTEM

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



LOW POWER GaAs PREPROCESSORS TECHNOLOGY

H. BENZ

SCOPE
TO IMPROVE ON CURRENT STATE OF ART GaAs DIGITAL AND MMIC TECHNOLOGY TO REDUCE POWER WHILE MAINTAINING RADIATION TOLERANCE AND PERFORMANCE.

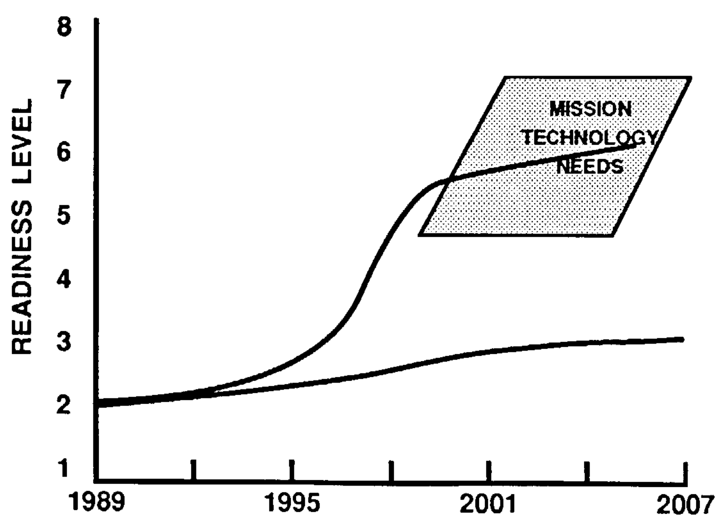
OBJECTIVES
- STUDY CANDIDATE FABRICATION TECHNOLOGIES.
- DEVELOP TEST AND LOGIC CELLS.
- DEVELOP INTEGRATED DEVICES.

RATIONALE
- RECENT IMPROVEMENTS IN SMALL CHIP YIELDS IN GaAs INDICATE THAT IT IS BECOMING SUFFICIENTLY MATURE TO BRING TO REAL SYSTEM USE.
- BRING 2 1/2 TIMES SPEED IMPROVEMENT AT SAME OR LOWER POWER AS SILICON CMOS.
- TECHNOLOGY DEVELOPMENT IN CONCERT WITH DARPA/SDIO.

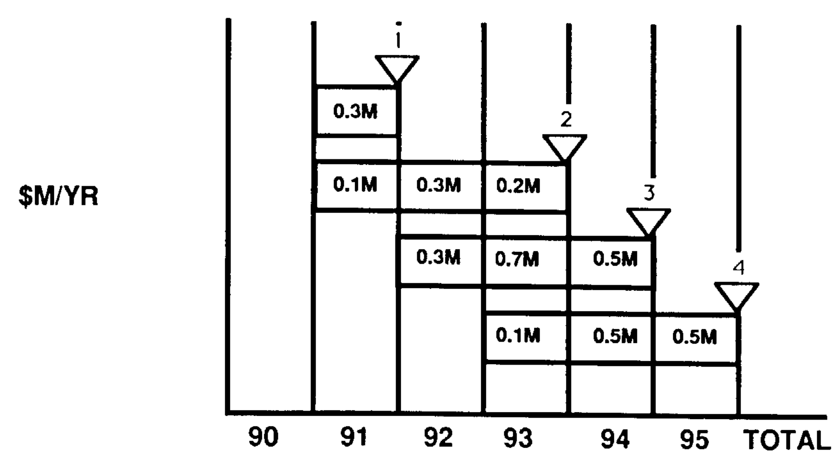
APPROACH
- STUDY POTENTIAL GaAs LOW POWER ALTERNATIVE LOGIC TO THE CURRENT MESFET, MODFET, HBT TECHNOLOGIES.
- USE VHDL AND GaAs COMPILERS TO DESIGN FUNCTIONAL CELLS.
- FABRICATE AND TEST CELLS IN CHIPS.
- USE OF U. of IDAHO WHERE APPLICABLE.

DELIVERABLES
1. REPORT OF RADIATION HARDENED LOW-POWER TECHNOLOGY
2. SPEED, POWER, MANUFACTURABILITY TESTS
3. PREPROCESSOR CHIP TEST
4. INTEGRATE INTO SYSTEM AND TEST

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



	90	91	92	93	94	95	TOTAL
TOTAL $M/YR		0.4	0.6	1.0	1.0	0.5	5.0

H. BENZ

MULTIPROCESSORS FOR SENSOR FUSION

SCOPE
RADIATION HARDENED MULTIPROCESSORS FOR SENSOR FUSION AND CONTROL.

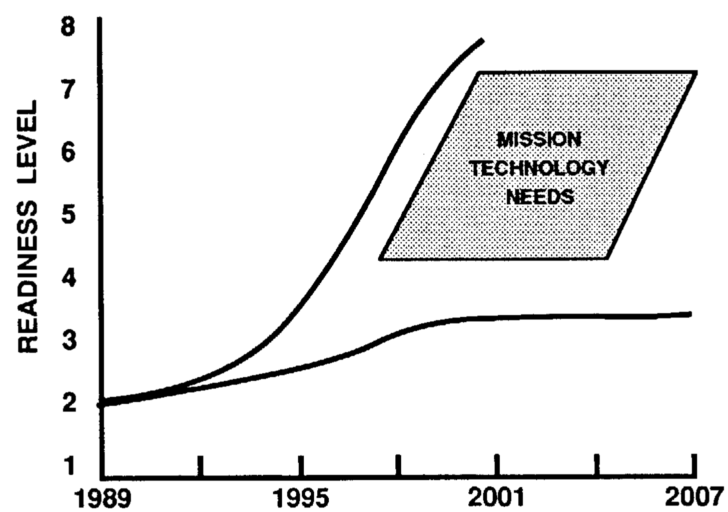
OBJECTIVES
- DEVELOP CURRENT GENERATION PROCESSOR CHIP TECHNOLOGY INTO NEXT GENERATION SYSTEMS APPLICATIONS.
- SUPPORT POLAR AND GEOSTATIONARY RADIATION REQUIREMENTS FOR LIMITED AMOUNTS OF ONBOARD SENSOR FUSION BETWEEN VARIOUS SENSING SYSTEMS WITH LOW POWER, MODEST COMPLEXITY SYSTEMS.

RATIONALE
- OPERATION AT GEO MUST MIX LASER COMM-LINKED GROUND PROCESSORS WITH RADIATION HARDENED ON-ORBIT COMPUTATIONAL HARDWARE.

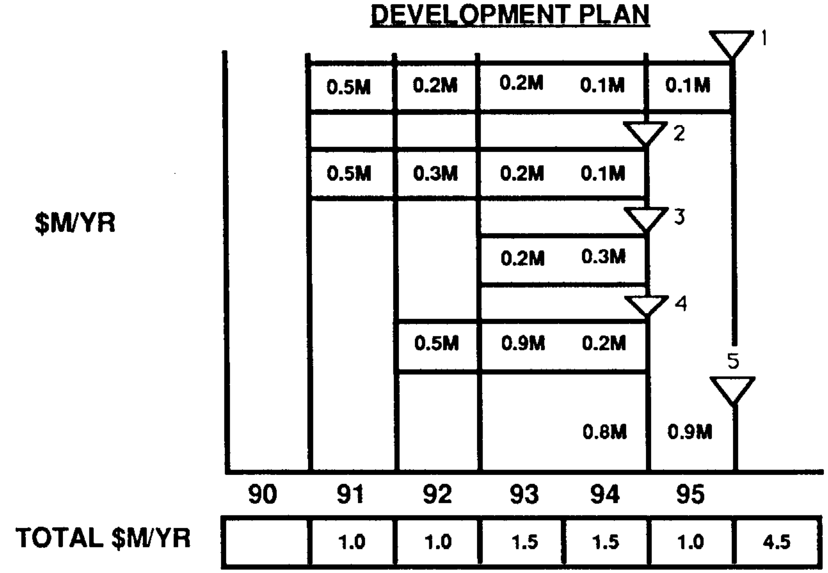
APPROACH
- USE CURRENT GENERATION 16-BIT AND LIMITED AMOUNT OF 32-BIT VON NEUMANN ARCHITECTED CHIP SETS TO DEVELOP CONCEPTS.
- BUILD ON CURRENT CSTI JOINT PROCESSOR DEVELOPMENT PROGRAM BETWEEN LANGLEY AND JPL BY AUGMENTATION OF MISSION APPLICATION STUDIES. DEVELOP TEST SIMULATIONS, DEMONSTRATE IN HARDWARE.

DELIVERABLES
1. MIXED-PROCESSOR GRAPHICAL THEORY
2. MULTIPROCESSOR OS SIMULATOR
3. DEVELOP ADA APPLICATION TEST PROGRAM
4. DEVELOP SYSTEM ARCHITECTURE
5. TEST/DEMO MULTIPROCESSOR SYSTEM

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



H. BENZ

SPACEBORNE 32-BIT RISC PROCESSOR CHIP SET

SCOPE
TO WORK JOINT PROGRAM WITH AF-RADC
TO CODEVELOP RH-32 CHIP SETS FOR GCTI
ONBOARD PROCESSING AND CONTROL APPLICATIONS.

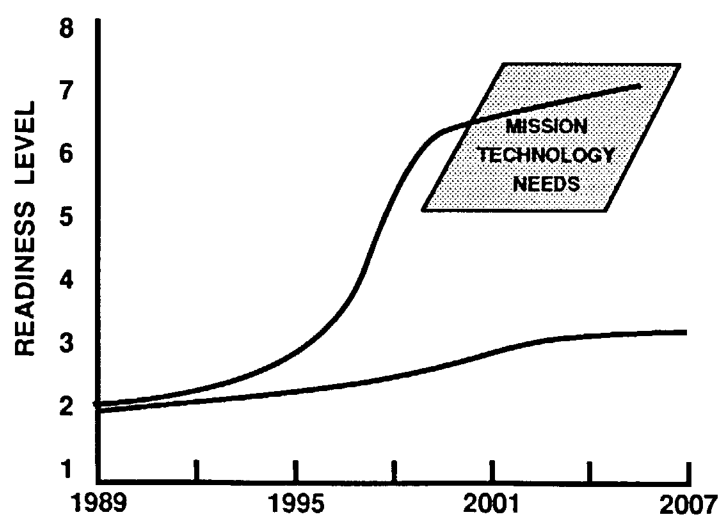
OBJECTIVES
- PROVIDE NEXT GENERATION ONBOARD PROCESSING CAPABILITY FOR CONTROL AND DATA HANDLING.
- SIMULTANEOUSLY MEET RAD-HARD, LOW POWER, HIGH PERFORMANCE GOALS WITH LIMITED FAULT TOLERANCE AND DATA INTEGRITY FOR NEXT-GENERATION EMBEDDED COMPUTER.
- LEVERAGE FROM BSTS, SSTS SYSTEM TECHNOLOGY DEVELOPMENTS.

RATIONALE
NEED HIGH PERFORMANCE PROCESSORS.
GEO POWER AND HEAT REJECTION EXPENSIVE.

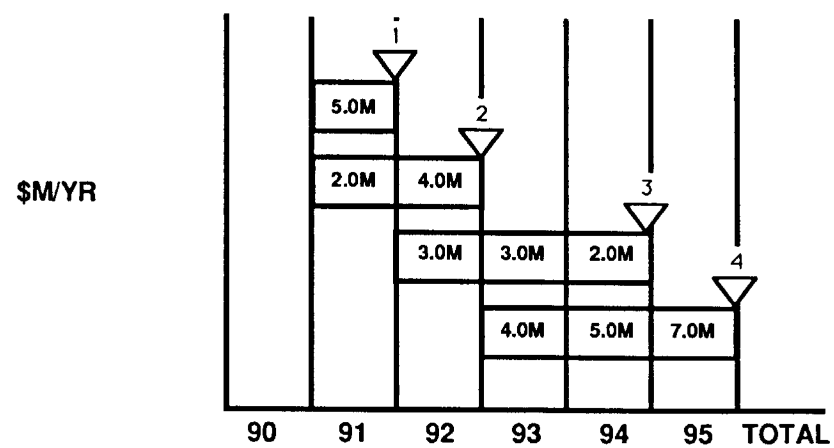
APPROACH
CODEVELOP WITH JOINT AF-RADC AND AF-STC AND SDIO PARTICIPATION, BOOTSTRAPPING ONTO THE DARPA CORE MIPS, AND AF-RADC RH-32 HARD AND MM AND FEASIBILITY PROGRAMS, AND USE EARLY LANGLEY PARTICIPATION IN THESE PROGRAMS.

DELIVERABLES
1. DESIGN OF CHIP SET
2. FIRST FAB AND TEST
3. DESIGN INTEGRATION
4. FINAL TEST IN COMPUTING ENVIRONMENT

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



	90	91	92	93	94	95	TOTAL
TOTAL $M/YR		7.0	7.0	7.0	7.0	7.0	35

M. BEATTY

16-BIT VHSIC 1750A SPACEFLIGHT COMPUTER UPGRADE

SCOPE
DEVELOP AND QUALIFY A HIGH-PERFORMANCE VHSIC UPGRADE TO THE EXISTING 16-BIT 1750A MAST COMPUTER.

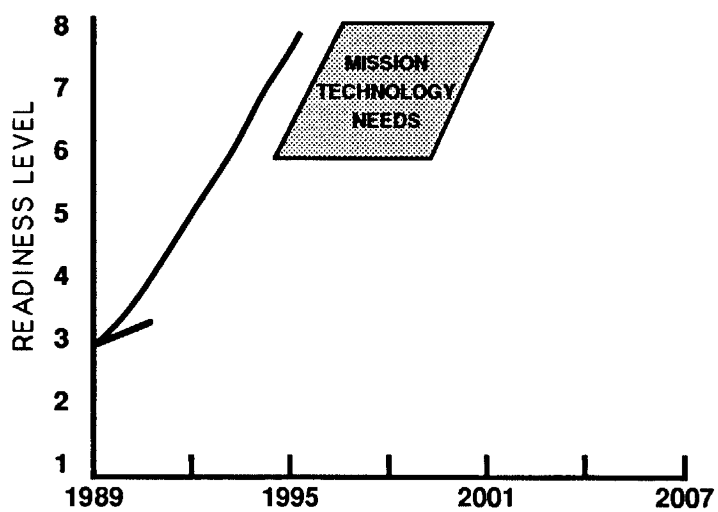
OBJECTIVES
- 3 MIPS PROCESSOR PERFORMANCE.
- 20 MIPS ARRAY PROCESSOR PERFORMANCE.
- 50 MBPS EXTERNAL DATA BUS RATE WITH FIBER OPTICS.
- 200% INCREASE IN MEMORY DENSITY, RAD-HARDENED.

RATIONALE
- HIGH-PERFORMANCE ON-ORBIT SENSOR DATA PROCESSING.
- FAULT TOLERANT PROCESSING FOR AUTONOMOUS SYSTEMS.
- IMPROVED REAL-TIME RESPONSE FOR DYNAMIC SYSTEMS.
- BASIC TECHNOLOGY LEVERAGED BY DOD PROGRAMS.
- SOFTWARE DEVELOPMENT ENVIRONMENT BEING DEVELOPED FOR CURRENT MAST SYSTEM.

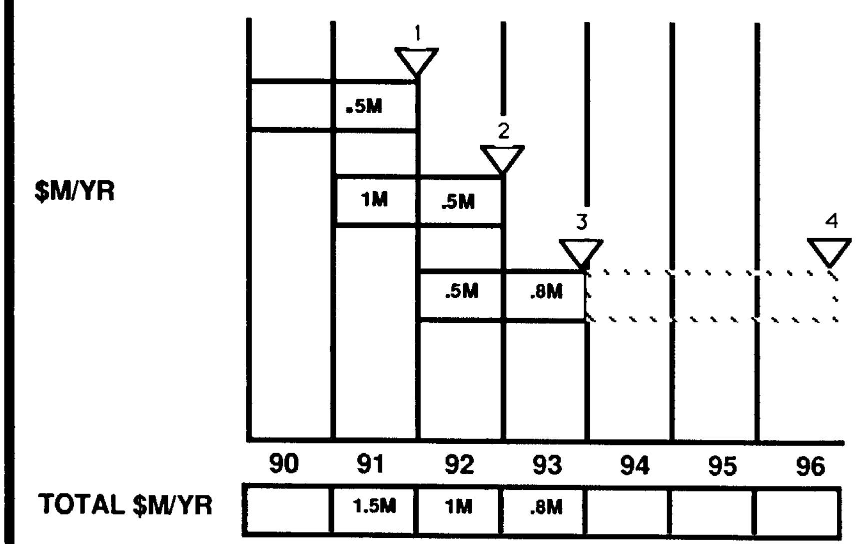
APPROACH
- MODIFY THE DESIGN OF THE CURRENT NASA MAST 1750A VLSI-BASED SPACE-QUALIFIED COMPUTER TO A GENERAL-PURPOSE SPACE-QUALIFIED VHSIC COMPUTER.
- BUILD UPON THE SOFTWARE DEVELOPMENT EFFORT SUPPORTING THE CURRENT MAST COMPUTER.

DELIVERABLES
1. GROUND SUPPORT EQUIPMENT AND SOFTWARE DEVELOPMENT ENVIRONMENT.
2. PROTOTYPE COMPUTER.
3. SPACE-QUALIFIED COMPUTER AND SPARE CARD SET.
4. SUSTAINED ENGINEERING.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



C-2

M. BEATTY

32-BIT VHSIC 1750A SPACEFLIGHT COMPUTER UPGRADE

SCOPE

DEVELOP AND QUALIFY A 32-BIT PROCESSOR UPGRADE TO THE EXISTING MAST COMPUTER; MAINTAIN ADA LANGUAGE SUPPORT CAPABILITY, WITH INTERNAL ARCHITECTURE CHANGES TO 32-BIT DATA PATHS AND EXPANDED ADDRESSING CAPABILITY.

OBJECTIVES

- HIGHER DATA PROCESSING/REDUCTION THROUGHPUT.
- LONG-TERM GROWTH CAPABILITY FOR ONBOARD PROCESSING.
- NEAR-TERM AVAILABILITY FOR FLIGHT APPLICATIONS.

RATIONALE

- HIGH PERFORMANCE ON-ORBIT SENSOR DATA PROCESSING.
- FAULT TOLERANT PROCESSING FOR AUTONOMOUS SYSTEMS.
- IMPROVED REAL-TIME RESPONSE FOR DYNAMIC SYSTEMS.
- TECHNOLOGY LEVERAGED BY DOD PROGRAMS (USAF RH-32).

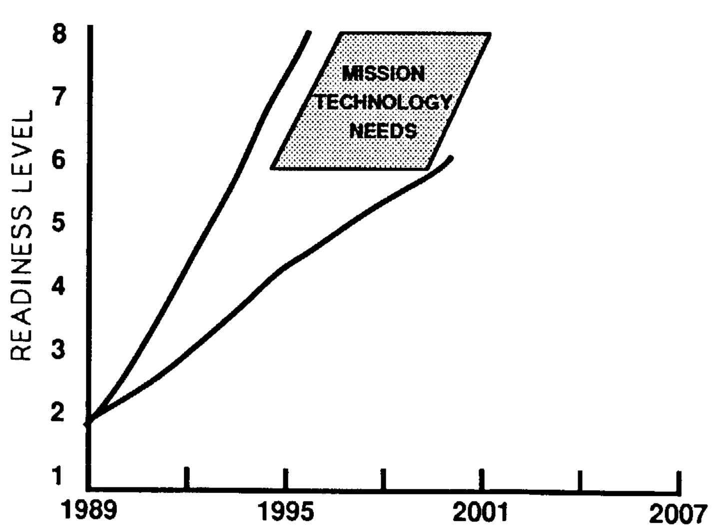
APPROACH

- MODIFY THE DESIGN OF THE CURRENT NASA MAST 1750A VLSI-BASED SPACE-QUALIFIED COMPUTER TO A GENERAL-PURPOSE SPACE-QUALIFIED VHSIC COMPUTER.
- BUILD UPON THE SOFTWARE DEVELOPMENT EFFORT SUPPORTING THE CURRENT MAST COMPUTER.

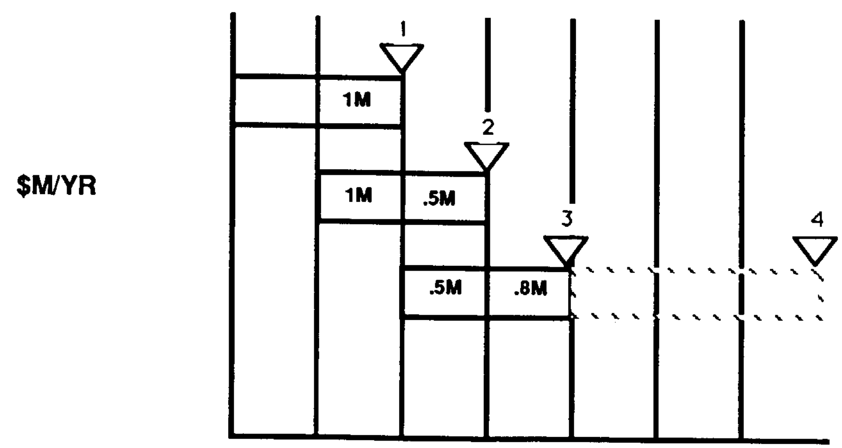
DELIVERABLES

1. GROUND SUPPORT EQUIPMENT AND SOFTWARE DEVELOPMENT ENVIRONMENT.
2. PROTOTYPE COMPUTER.
3. SPACE QUALIFIED COMPUTER AND SPARE CARD SET.
4. SUSTAINED ENGINEERING.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



TOTAL $M/YR	90	91	92	93	94	95	96
		2M	1M	.8M			

H. HENDRICKS

HIGH-PERFORMANCE LASER FOR OPTICAL RECORDING

SCOPE

DEVELOP AND DEMONSTRATE HIGH-PERFORMANCE LASER FOR OPTICAL RECORDING.

OBJECTIVE

- REDUCE LASER WAVELENGTH.
- IMPROVE LASER STABILITY AND MODULATION RATE.
- INCREASE LASER POWER EFFICIENCY.

RATIONALE

SHORTER WAVELENGTH LASERS WILL PROVIDE INCREASED OPTICAL RECORDING CAPACITY.

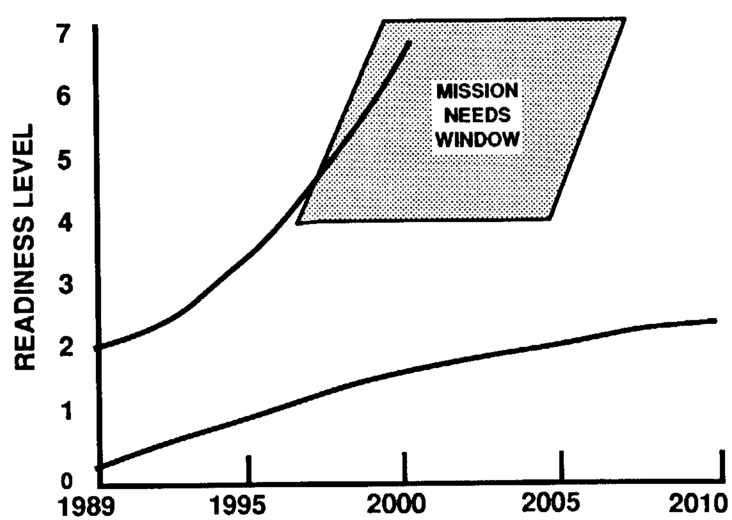
APPROACH

DEVELOP SHORTER WAVELENGTH SEMICONDUCTOR (SC) LASER MATERIAL AND DEVICE DESIGN. FABRICATE, DESIGN, AND CHARACTERIZE LASER, AND DEVELOP STABLE AND LONG LIFE SC LASER.

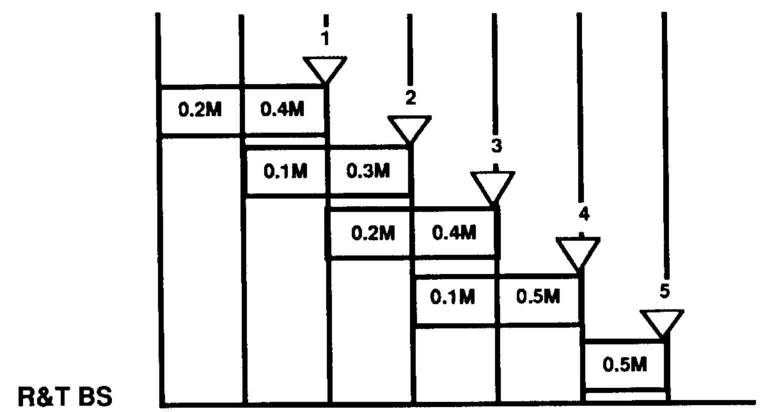
DELIVERABLES

- MATERIAL SYSTEM AND INITIAL DESIGN.
- DEMONSTRATION OF INITIAL SC LASER.
- ENGINEERING DESIGN MODEL LASER.
- LONG LIFE AND STABLE LASER.
- SPACE-QUALIFIED SC LASER.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



	90	91	92	93	94	95	TOTAL
TOTAL $M/YR	0.2	0.5	0.5	0.5	0.5	0.5	2.7M
TOTAL MY/YR		1.0	1.0	2.0	2.0	2.0	8.0

N. MURRAY

HIGH-PERFORMANCE PHOTONIC NETWORK DEVELOPMENT

SCOPE
RESEARCH AND DEMONSTRATE A HIGH-PERFORMANCE ALL PHOTONIC NETWORK FOR ONBOARD EARTH-OBSERVING SATELLITES.

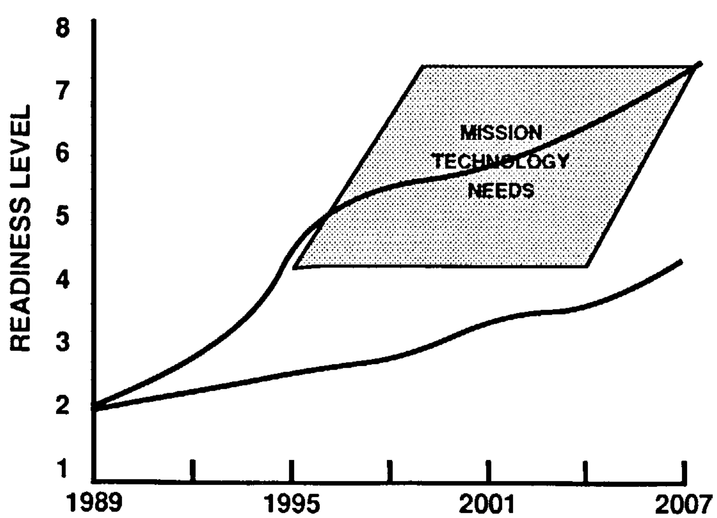
OBJECTIVES
- RESEARCH AND DEFINE THE ARCHITECTURAL ISSUES FOR AN ALL PHOTONIC NETWORK.
- RESEARCH AND DEVELOP AN ADAPTABLE OPTIC NODE FOR SELECTED ARCHITECTURES.
- INTEGRATE THE OPTIC NODE INTO PHOTONIC NETWORK TEST BED DEMONSTRATION.

RATIONALE
ENABLE SCIENCE USERS DIRECT ACCESS TO SENSOR DATA AND GLOBAL INFORMATION.

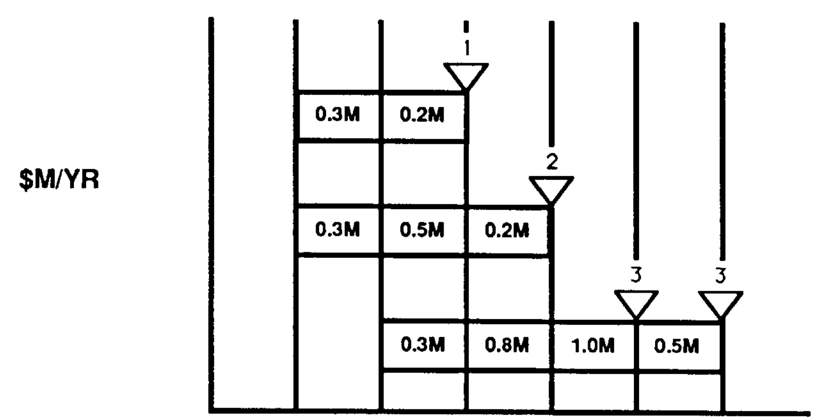
APPROACH
USE ONGOING RESEARCH PRODUCTS FROM NASA, UNIVERSITIES, AND INDUSTRY; NASA UNDERTAKE NEW AND INNOVATIVE RESEARCH TO MEET UNIQUE REQUIREMENTS.

DELIVERABLES
1. ARCHITECTURE DEFINITION AND MODELING.
2. OPTIC NODE DEVELOPMENT.
3. PHOTONIC NETWORK BUILD - MINIDEMO.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



	90	91	92	93	94	95	TOTAL
TOTAL $M/YR		0.6	1.0	1.0	1.0	0.5	4.1

T. SHULL

SPACEFLIGHT OPTICAL DISK RECORDER

SCOPE
DEVELOP HIGH-PERFORMANCE REWRITABLE OPTICAL DISK MASS STORAGE SYSTEM FOR SPACEFLIGHT APPLICATIONS.

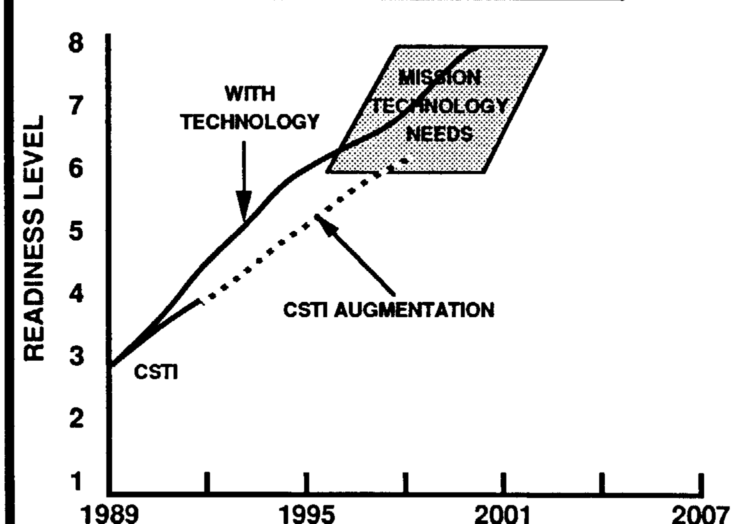
OBJECTIVES
- UP TO 1.8 GIGABIT/SEC I/O RATE.
- CAPACITY TO TERABIT (120 GIGABYTE).
- RANDOM FILE ACCESS (100 MSEC) .
- SIMULTANEOUS INPUT AND OUTPUT.

RATIONALE
HIGH-SPEED/HIGH-CAPACITY MASS STORAGE NEEDED FOR FUTURE MISSIONS. ALLOWS PRIORITY DOWNLINK AND ONBOARD PROCESSING.

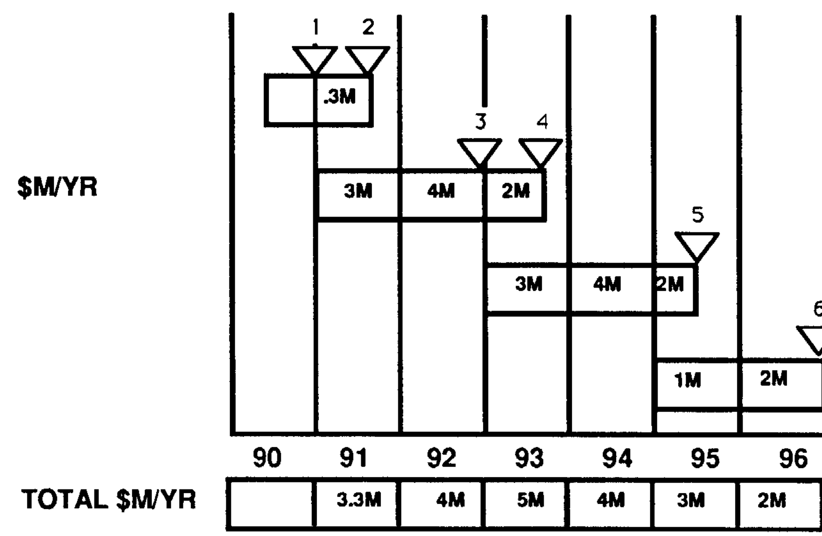
APPROACH
- LEVERAGE EXISTING CSTI AND DOD PROGRAMS.
- USE VERSATILE EXPANDABLE SYSTEM ARCHITECTURE BASED ON SINGLE DISK DRIVES AND MODULAR CONTROLLER.
- DEVELOP AND QUALIFY MODULES.
- DEMONSTRATE SYSTEM CONCEPT.

DELIVERABLES
1. ADVANCED DEVELOPMENT UNIT FROM CSTI.
2. SYSTEM MODELS.
3. ENGINEERING DEMONSTRATION UNIT.
4. TEST BED SYSTEM DEMONSTRATION.
5. FLIGHT PROTOTYPE DRIVE AND CONTROLLER.
6. FLIGHT TEST MINIMUM SYSTEM.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



INTEGRATED DATA PROCESSOR/SMART SENSOR CONCEPTS

SCOPE

DEVELOP AND DEMONSTRATE ONBOARD DATA PROCESSOR ENBEDDED IN MICROWAVE AND OPTICAL SENSOR SYSTEMS.

OBJECTIVE

- INTEGRATED SENSOR ANALOG SIGNAL PROCESSING WITH DIGITAL PROCESSOR.
- DEMONSTRATE AUTOMATED SIGNAL PROCESSING.
- DEMONSTRATE SENSOR CALIBRATION AND SYSTEM CONTROLLER PROCESSOR.

RATIONALE

REMOTE ONBOARD SENSOR SYSTEM REQUIRES AUTOMATED AND INTEGRATED PROCESSOR.

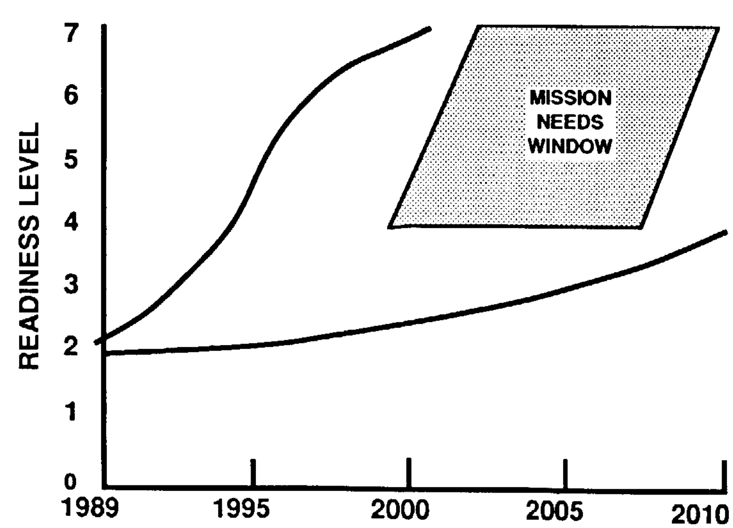
APPROACH

UTILIZE ANALOG AND DIGITAL INTEGRATED CIRCUIT DESIGN TO IMPLEMENT SMART SENSOR PROCESSOR. DEVELOP INTEGRATED SENSOR/PROCESSOR FOR MICROWAVE AND OPTICAL SENSORS.

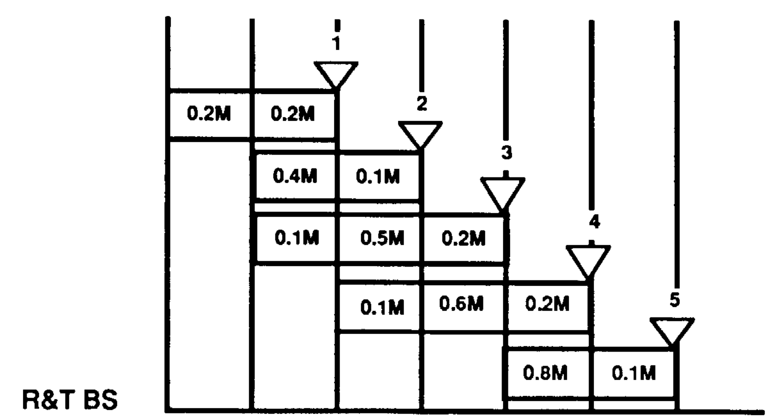
DELIVERABLES

- RADIATION-HARDENED PROCESSOR DESIGN.
- SENSOR/PROCESSOR INTEGRATION DESIGN.
- INITIAL SENSOR/PROCESSOR.
- FULL SENSOR/PROCESSOR WITH CALIBRATION.
- SPACE-QUALIFIED INTEGRATED PROCESSOR.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



	90	91	92	93	94	95	TOTAL
TOTAL $M/YR	0.2	0.7	0.7	0.8	1.0	0.1	2.6M
TOTAL MY/YR		2.0	2.0	3.0	4.0	4.0	15.0

R. HOLLOWAY

SENSOR SPECIFIC PREPROCESSING

SCOPE
DEVELOP HIGH-PERFORMANCE DETECTOR SPECIFIC PREPROCESSING COMPONENTS FOR SPACEBORNE REMOTE SENSING INSTRUMENTS.

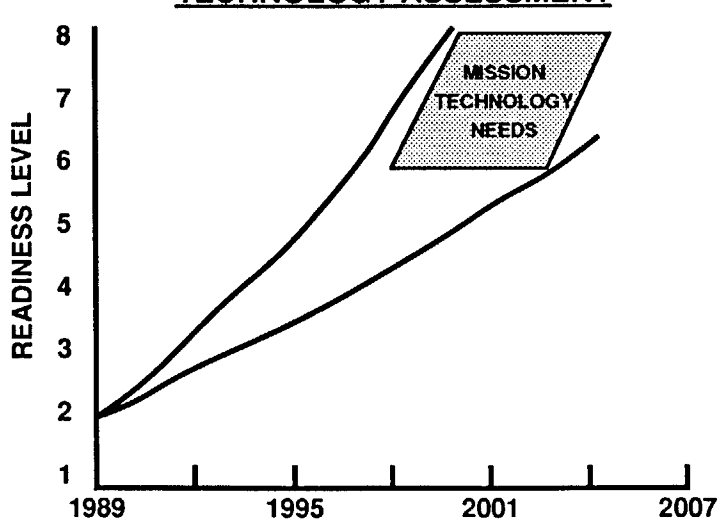
OBJECTIVES
- FLIGHT QUALIFY SPECIAL PURPOSE PREPROCESSING ELEMENTS.
- DEVELOP AND DEMONSTRATE SYSTEM PERFORMANCE.
- DEVELOP AGENCY-WIDE CAPABILITIES TO APPLY ADVANCED TECHNOLOGIES TO FUTURE MISSIONS.

RATIONALE
MEASUREMENTS OF GLOBAL CHANGE PHENOMENA WILL REQUIRE UNPRECEDENTED DYNAMIC RANGE AND SIGNAL-TO-NOISE RATIO. MISSION LENGTH REQUIRES THE RELIABILITY AND INHERENT STABILITY OF DIGITAL PREPROCESSING. INCREASED SYSTEM BANDWIDTH IS REQUIRED TO PROCESS AND TRANSMIT DATA IN REAL-TIME.

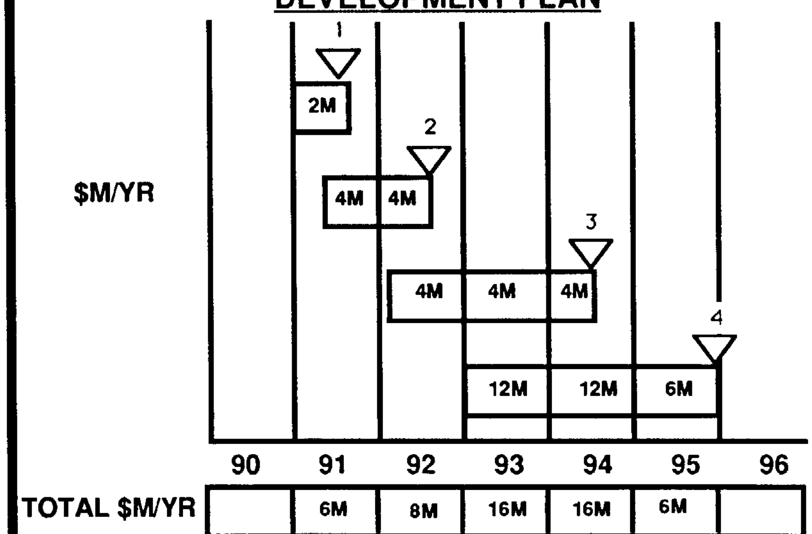
APPROACH
- ASSESS NASA REQUIREMENTS VERSUS AVAILABLE TECHNOLOGIES.
- ESTABLISH AGENCY-WIDE FACILITIES TO PROVIDE TOOLS FOR COMPONENT DEVELOPMENT .
- IDENTIFY LONG-TERM SOURCES FOR FLIGHT QUALIFIED PARTS.
- DESIGN, FABRICATE, AND TEST PREPROCESSING SYSTEM IN TARGET INSTRUMENTS.

DELIVERABLES
1. SELECTED INSTRUMENT FOR ADVANCE PREPROCESSING COMPONENTS.
2. SYSTEMS TO DEVELOP ALGORITHM AND DESIGN COMPONENTS.
3. PREPROCESSING ALGORITHMS AND DESIGNS.
4. FLIGHT-QUALIFIED SYSTEMS.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



LaRC GCTI Information Technologies

3.3 Information Transfer

Technology	NASA GCTI WBS	Proposal funding requirements, millions of dollars					
		FY90	FY91	FY92	FY93	FY94	FY95
High performance semiconductor lasers	3.31–1	0.5	0.5	0.5	0.8	0.8	0.8
Optical crosslink communications	3.31–2		5.0	5.0	6.0	8.0	10.0
Optical backplane interconnect			0.5	0.5	0.5	0.5	0.5
High speed fiber optic transceiver	3.32–1	0.5	0.3	0.4	0.5	1.0	
Totals		1.0	6.3	6.4	7.8	10.3	11.3

H. HENDRICKS

HIGH-PERFORMANCE SEMICONDUCTOR LASERS

SCOPE

DEVELOP AND DEMONSTRATE HIGH-POWER AND HIGH-DATA-RATE SEMICONDUCTOR (SC) LASER FOR OPTICAL COMMUNICATION.

OBJECTIVE

- DEMONSTRATE HIGH-POWER SC LASER.
- DEMONSTRATE HIGH-DATA-RATE LASER.
- DEMONSTRATE STABLE AND LONG LIFE SPACE QUALIFIED SC LASER.

RATIONALE

HIGH-PERFORMANCE SC LASER WILL ENABLE HIGH-DATA-RATE OPTICAL COMMUNICATION SYSTEM.

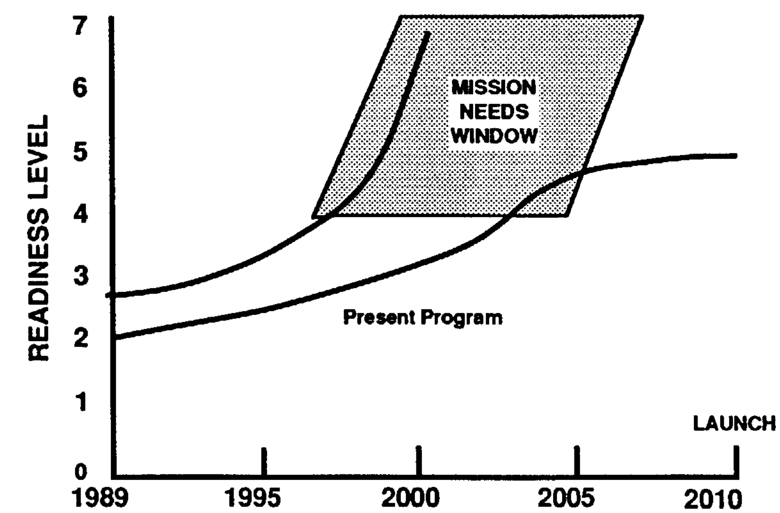
APPROACH

UTILIZE AlGaAs QUANTUM WELL(QW) DESIGN WITH GRATING; FABRICATE AND TEST DESIGN; ITERATE LASER DESIGN FOR LONG LIFE, STABLE, AND SPACE-QUALIFIED SC LASER.

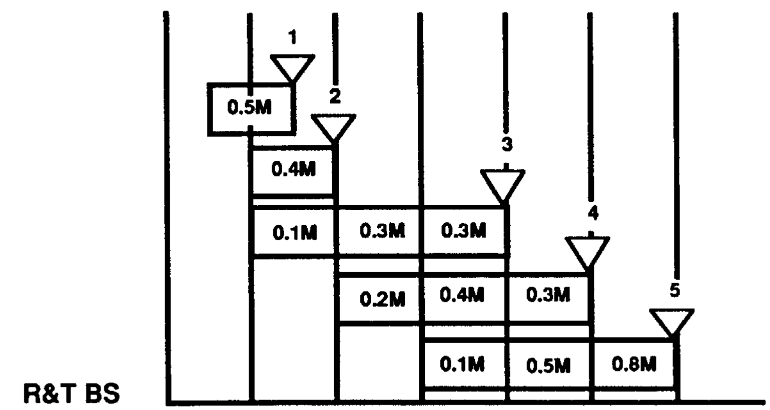
DELIVERABLES

- INITIAL QW AND DFB LASER DESIGN.
- INITIAL LASER DEMONSTRATION.
- HIGH-SPEED/POWER SC LASER.
- STABLE AND LONG LIFE LASER.
- SPACE-QUALIFIED LASER.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



	90	91	92	93	94	95	TOTAL
TOTAL $M/YR	0.5	0.5	0.5	0.8	0.8	0.8	3.9M
TOTAL MY/YR		2.0	2.0	2.0	2.0	2.0	10.0

H. HENDRICKS

HIGH-PERFORMANCE OPTICAL CROSSLINK COMMUNICATIONS

SCOPE

DEVELOP AND DEMONSTRATE HIGH -PERFORMANCE OPTICAL CROSSLINK FOR HIGH-CAPACITY SENSOR DATA TRANSFER.

OBJECTIVE

- DEMONSTRATE HIGH-DATA-RATE OPTICAL COMMUNICATION LINKS.
- DEMONSTRATE TRACKING, POINTING, AND ACQUISITION SYSTEM.
- SPACE QUALIFICATION OF OPTICAL COMMUNICATION SYSTEM.

RATIONALE

OPTICAL COMMUNICATION LINK WILL ENABLE HIGH-DATA-RATE TRANSFER OF SENSOR INFORMATION.

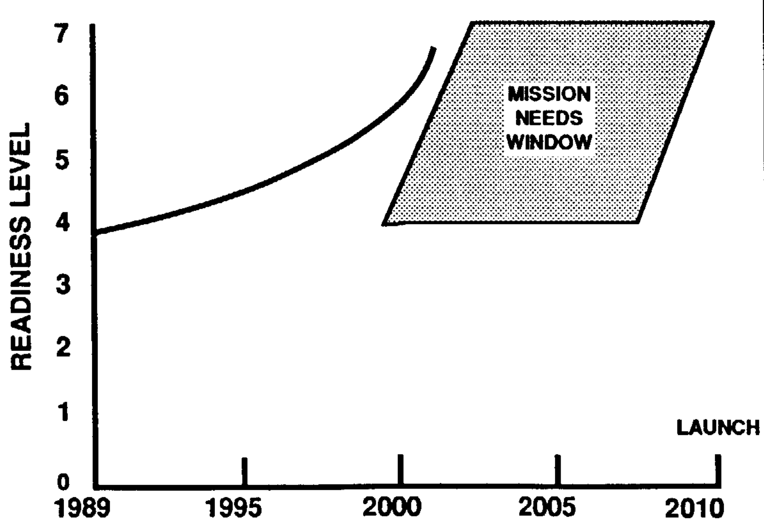
APPROACH

DEMONSTRATE OPTICAL AND ELECTRONIC SYSTEM COMPONENTS, VALIDATE TRACKING SYSTEM, DEMONSTRATE OPTICAL LINK CAPABILITY, AND SPACE QUALIFY OPTICAL CROSSLINK SYSTEM.

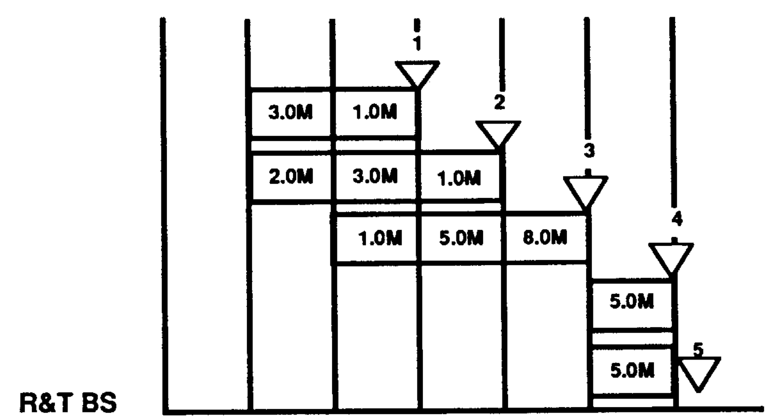
DELIVERABLES

- DEMONSTRATION OF SYSTEM COMPONENTS.
- VALIDATION OF SYSTEM DESIGN.
- OPERATIONAL DEMONSTRATION OF LINK.
- SPACE QUALIFICATION OF SYSTEM.
- DELIVERY OF CROSSLINK SYSTEM.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



	90	91	92	93	94	95	TOTAL
TOTAL $M/YR		5.0	5.0	6.0	8.0	10.0	34.0M
TOTAL MY/YR		20	20	20	20	20	100

H. HENDRICKS

OPTICAL BACKPLANE INTERCONNECT SWITCH (OBIS)

SCOPE

DEVELOP HIGH-PERFORMANCE OBIS FOR DATA PROCESSOR AND COMPUTER COMMUNICATIONS.

OBJECTIVE

- VALIDATE OBIS INTEGRATED OPTICS DESIGN.
- DEMONSTRATE INITIAL 4 x 4 OBIS.
- DEMONSTRATE 32 x 32 OBIS.

RATIONALE

OPTICAL SWITCHING REDUCES DIGITAL DELAYS AND BOTTLENECKS IN DATA SYSTEM.

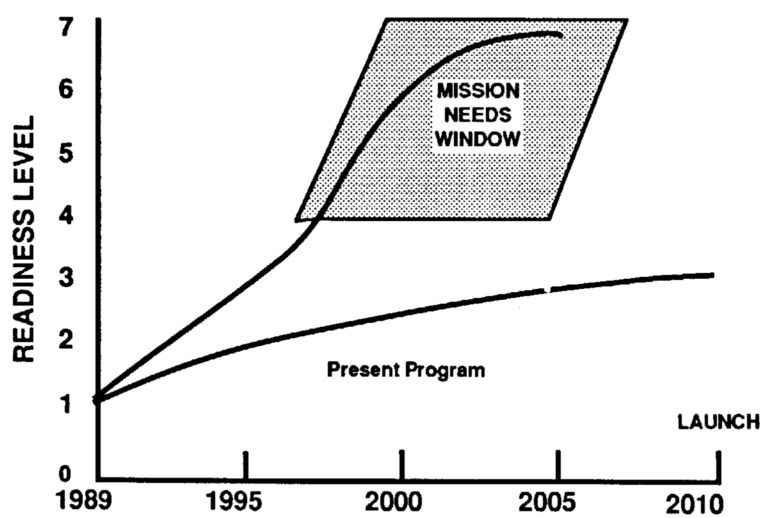
APPROACH

BUILD UPON DEMONSTRATED OPTICAL SWITCHING, FABRICATE INTEGRATED OPTICS DESIGN, DEMONSTRATE DESIGN PERFORMANCE, AND EXTEND DESIGN TO LARGER OBIS ARRAYS.

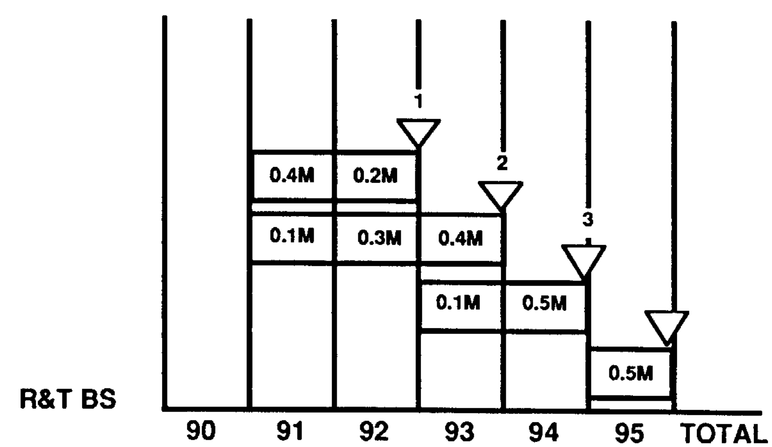
DELIVERABLES

- VALIDATE OBIS DESIGN.
- DEMONSTRATE INITIAL OBIS PERFORMANCE.
- DEMONSTRATE 4 x 4 OBIS.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



	90	91	92	93	94	95	TOTAL
TOTAL $M/YR		0.5	0.5	0.5	0.5	0.5	2.5M
TOTAL MY/YR		0.5	0.5	0.5	0.5	0.5	2.5

H. HENDRICKS

HIGH SPEED FIBER OPTIC TRANSCEIVER

SCOPE

DEVELOP, DEMONSTRATE, AND SPACE QUALIFY HIGH SPEED FIBER OPTICS (FO) TRANSCEIVER.

OBJECTIVE

- DESIGN AND FABRICATE INTEGRATED CIRCUIT FIBER OPTIC TRANSCEIVER.
- DEMONSTRATE 0.05 - 4 GBITS/SEC FO TRANSCEIVER (TX/RX)
- SPACE QUALIFY TRANSCEIVER.

RATIONALE

SPACE DATA SYSTEMS NEED NONEXISTENT HIGH-SPEED AND SPACE-QUALIFIED FO TX/RX.

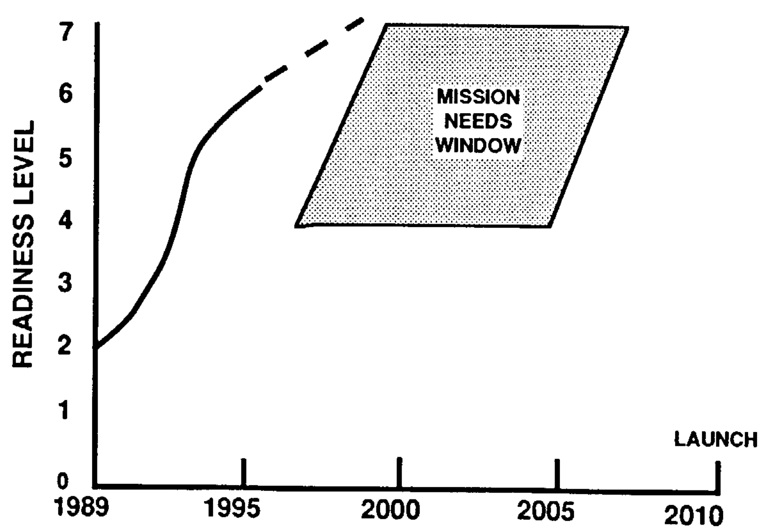
APPROACH

JOINT AF/NASA PROGRAM. PERFORM CAD DESIGN AND VALIDATE, FABRICATE DESIGN, AND MIL/SPACE QUALIFY FIBER-OPTIC TRANSCEIVER FOR LEO AND GEO ENVIRONMENT.

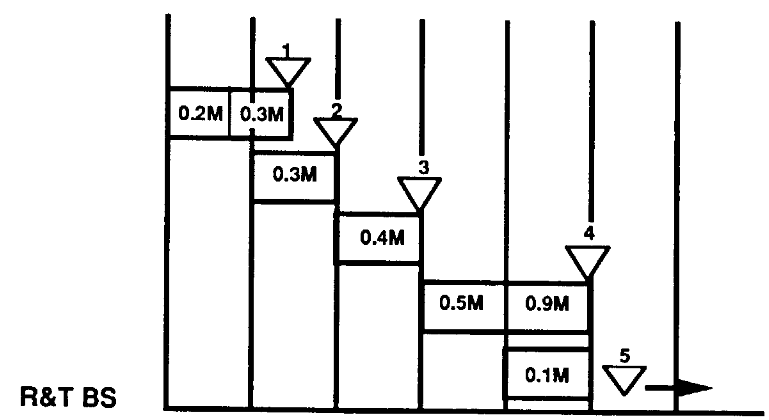
DELIVERABLES

- VALIDATED CAD TRANSCEIVER DESIGN.
- ENGINEERING DESIGN MODEL TRANSCEIVER.
- 0.05 - 4 GBITS/SEC TRANSCEIVER.
- SPACE-QUALIFIED FO TRANSCEIVER.
- FINAL DESIGN SPECIFICATIONS AND REPORT.

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



	90	91	92	93	94	95	TOTAL
TOTAL $M/YR	0.5	0.3	0.4	0.5	1.0		2.7M
TOTAL MY/YR		1.0	1.0	1.0	1.0		4.0

LaRC GCTI Information Technologies

3.4 Ground Element

Technology	NASA GCTI WBS	Proposal funding requirements, millions of dollars					
		FY90	FY91	FY92	FY93	FY94	FY95
Ground-based optical disk	3.41–6		0.5	1.0	1.5	1.5	2.0
Totals			0.5	1.0	1.5	1.5	2.0

T. SHULL

GROUND-BASED OPTICAL DISK MASS STORAGE SYSTEM

SCOPE

DEVELOP A HIGH-PERFORMANCE REWRITABLE OPTICAL DISK MASS STORAGE SYSTEM TO SUPPORT ON-LINE MISSION OPERATIONS.

- REAL-TIME DATA RECORDING
- MULTIPLE USER NEAR REAL-TIME ACCESS TO SCIENCE & ENGINEERING DATA

OBJECTIVES

- CAPACITY TO A TERABYTE
- RAPID FILE ACCESS (100 MILLISECONDS)
- 300 MEGABIT/SECOND INPUT/OUTPUT RATE

RATIONALE

- SUPPORT EOS TERABIT/DAY AT 300 MBITS/SEC
- RAPID DATA ACCESS FOR SCIENTIFIC AND ENGINEERING ANALYSIS
- BROAD SUPERCOMPUTER APPLICATION

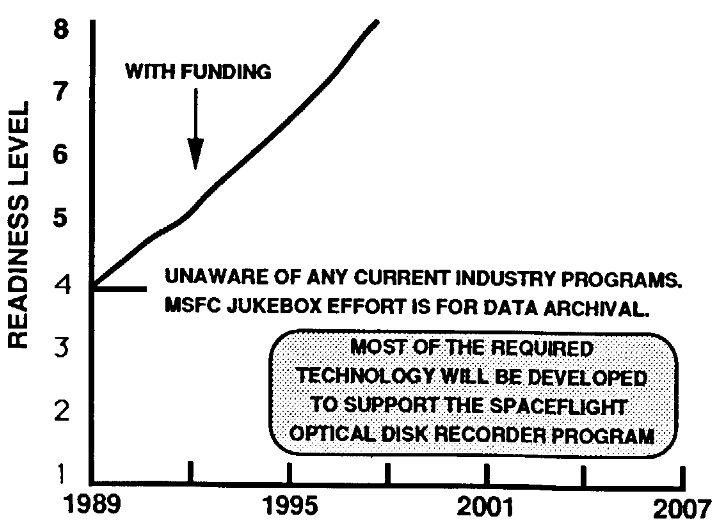
APPROACH

- LEVERAGE TECHNOLOGY FROM EXISTING NASA AND DOD OPTICAL DISK PROGRAMS
- SEEK INDUSTRY PARTICIPATION/LEVERAGING IN SUPPORT OF FUTURE COMMERCIAL APPLICATIONS/MARKET-SHARE
- COMBINED NASA, DOD, AND INDUSTRY CONCEPT & REQUIREMENTS TO SUPPORT MULTIPLE APPLICATIONS

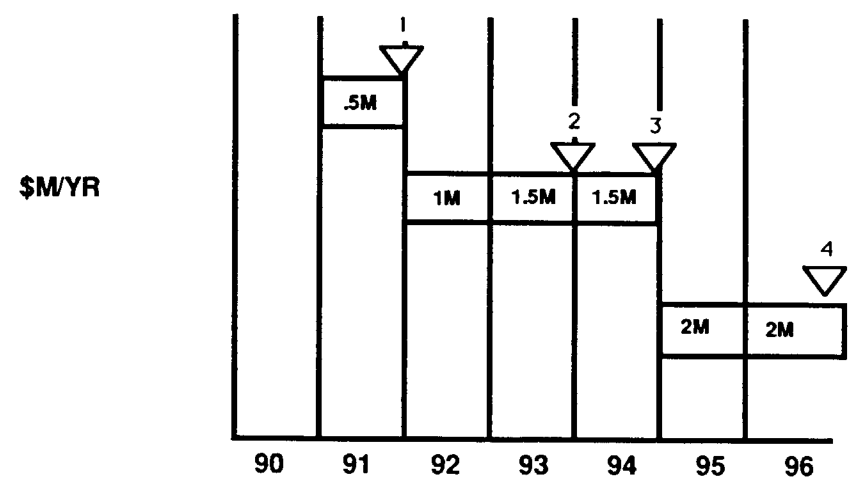
DELIVERABLES

1. SYSTEM CONCEPTUAL DESIGN
2. PROTOTYPE/DEMONSTRATION SYSTEM
3. TEST BED SYSTEM DEMONSTRATION
4. OPERATIONAL SYSTEM

TECHNOLOGY ASSESSMENT



DEVELOPMENT PLAN



	90	91	92	93	94	95	96
TOTAL $M/YR		.5M	1M	1.5M	1.5M	2M	2M

Table I. Global Change Science Measurement Requirements

Measurement	Location	Temporal resolution	Spatial resolution	Accuracy required	Comments	Measurement method (a)	Source (b)
Solar irradiance	Sun disk	1 day [c](1 sec)		0.10%	Total	Radiometer	1, 4
UV	Sun disk	7 day [c](1 min)		0.10%	Ongoing	UV spectroscopy	1, 4
Index of volcanic emissions (see aerosols, gases, atmospheric temperature, ocean surface temperature)	Site specific				Irregular observation, in situ measurements	Visible	1
CO_2	Troposphere	1-3 hr	10 × 10 × 1 km 100 × 100 × 1 km	1%	In situ	Lidar IR spectrometry	1
N_2O	Troposphere	1–3 hr	100 × 100 × 1 km	1%		IR: interferometry, emission, occultation	1
CH_4	Troposphere	1–3 hr	100 × 100 × 1 km	1%		IR: interferometry, emission, occultation	1, 4
CFM's	Troposphere	1–3 hr	100 × 100 × 1 km	1%		IR interferometry, IR spectrometry (2–20 μm), lidar	1
Troposphere O_3	Troposphere	1–3 hr 1–3 hr	10 × 10 × 1 km 100 × 100 × 1 km	1% 1%		Lidar IR: interferometry, emission, occultation	1, 4
Troposphere CO	Troposphere	1–3 hr	10 × 10 × 1 km	1%		IR: spectrometry, emission	1, 4
Troposphere COS	Troposphere	2 week	200 × 200 × 3 km	1%		IR: spectrometry, lidar	2, 3
Troposphere H_2O	Troposphere	[c]1–12 hr [c]1–12 hr	100 × 100 × 1 km 10 × 10 × 1 km	1% 1%		IR: spectrometry Lidar	2, 3, 4
Troposphere H_2O_2	Troposphere	1–3 hr	10 × 10 × 1 km	1%		IR: spectrometry, lidar	2, 3

Footnotes are at end of table, page 116.

Table I. Continued

Measurement	Location	Temporal resolution	Spatial resolution	Accuracy required	Comments	Measurement method (a)	Source (b)
Troposphere NO	Troposphere	1–3 hr	10 × 10 × 1 km	1%		IR: spectrometry, lidar	2, 3
Troposphere NO_2	Troposphere	1–3 hr	10 × 10 × 1 km	1%		IR: spectrometry, lidar	2, 3
Troposphere HNO_3	Troposphere	1–3 hr	10 × 10 × 1 km	1%		IR: spectrometry, lidar	2, 3
Troposphere NH_3	Troposphere	1–3 hr	10 × 10 × 1 km	1%		IR: spectrometry, lidar	2, 3
Troposphere C_2H_6	Troposphere	1 3 hr	10 × 10 × 1 km	1%		IR: spectrometry, lidar	2
Troposphere C_2H_2	Troposphere	1–3 hr	10 × 10 × 1 km	1%		IR: spectrometry, lidar	2
Troposphere SO_2	Troposphere	1–3 hr	10 × 10 × 1 km	1%		IR: spectrometry, lidar	2, 3
Troposphere OH	Troposphere	1–3 hr	10 × 10 × 1 km	1%	Low concentration, difficult, need technology development	Lidar, UV	2, 3
Stratosphere O_3	Stratosphere	[c]1–12 hr	10 × 10 × 1 km	1%	Day and night	UV, sondes, microwave, lidar IR: emission, interferometry, occultation	1, 4
Stratosphere H_2O	Stratosphere	3–12 hr	500 × 500 × 3.5 km	5%		IR: emission, interferometry, occultation Microwave, submillimeter	1
Stratosphere NO_2	Stratosphere	3–12 hr	500 × 500 × 3.5 km	5%		Occultation, visible spectrometry, submillimeter IR: emission, interferometry	1
Stratosphere HNO_3	Stratosphere	3 12 hr	500 × 500 × 3.5 km	5%	Various methods	IR: limb scan Submillimeter	1
Stratosphere HCl	Stratosphere	3 12 hr	500 × 500 × 3.5 km	5%		IR: interferometry, emission, occultation Microwave, submillimeter	1

Footnotes are at end of table, page 116.

Table I. Continued

Measurement	Location	Temporal resolution	Spatial resolution	Accuracy required	Comments	Measurement method (a)	Source (b)
Stratosphere aerosols	Stratosphere	[c]1–12 hr	200 × 500 × 1 km	25%		Occultation, lidar	1, 4
Stratosphere O	Stratosphere	3–12 hr	500 × 500 × 3.5 km	5%	FIR bands, valuable for stratospheric species, day and night	Submillimeter	2
Stratosphere O_2	Stratosphere	3–12 hr	500 × 500 × 3.5 km	5%		Visible/IR/FIR spectrometry Lidar, microwave	3
Stratosphere CO	Stratosphere	3–12 hr	500 × 500 × 3.5 km	5%		IR spectrometry, microwave	2, 3
Stratosphere HOCl	Stratosphere	3–12 hr	500 × 500 × 3.5 km	5%		IR spectrometry, microwave, submillimeter	2, 3
Stratosphere OClO	Stratosphere	3–12 hr	500 × 500 × 3.5 km	5%		IR spectrometry, submillimeter	2, 3
Stratosphere OH	Stratosphere	3–12 hr	500 × 500 × 3.5 km	5%	Difficult	FIR spectrometry, microwave, submillimeter	2, 3
Stratosphere HO_2	Stratosphere	3–12 hr	500 × 500 × 3.5 km	5%		IR spectrometry, microwave, submillimeter	2, 3
Stratosphere H_2O_2	Stratosphere	3–12 hr	500 × 500 × 3.5 km	5%		IR spectrometry, microwave, submillimeter	2, 3
Stratosphere NO	Stratosphere	3–12 hr	500 × 500 × 3.5 km	5%		IR spectrometry, submillimeter	2, 3
Stratosphere N_2O	Stratosphere	3–12 hr	500 × 500 × 3.5 km	5%		IR spectrometry, microwave, submillimeter	2, 3
Stratosphere N_2O_5	Stratosphere	3–12 hr	500 × 500 × 3.5 km	5%		Visible/IR/FIR spectrometry, lidar, microwave	3
Stratosphere ClO	Stratosphere	3–12 hr	500 × 500 × 3.5 km	5%		IR spectrometry, microwave, submillimeter	2, 3

Footnotes are at end of table, page 116.

Table I. Continued

Measurement	Location	Temporal resolution	Spatial resolution	Accuracy required	Comments	Measurement method (a)	Source (b)
Stratosphere $ClONO_2$	Stratosphere	3–12 hr	500 × 500 × 3.5 km	5%		IR spectrometry	2, 3
Stratosphere BrO	Stratosphere	3–12 hr	500 × 500 × 3.5 km	5%		IR spectrometry, submillimeter	2, 3
Stratosphere HBr	Stratosphere	3–12 hr	500 × 500 × 3.5 km	5%		IR/FIR spectrometry	3
Stratosphere CH_4	Stratosphere	3–12 hr	500 × 500 × 3.5 km	5%		IR: interferometry, emission, occultation	1
Stratosphere CFM's	Stratosphere	3–12 hr	500 × 500 × 3.5 km	5%		IR: interferometry, spectrometry (2–20 μm) Lidar	1
Troposphere temperature	Troposphere	[c]15 min–3 hr	100 × 100 × 5 km	0.5 K		Sondes, IR, microwave	1, 4
Stratosphere temperature	Stratosphere	1–3 hr	500 × 500 × 3.5 km	1 K		Sondes, IR, microwave, IR limb scan	1
Surface pressure	Earth surface	[c]0.5–3 hr	100 × 100 km	1 mbar	In situ	Microwave	1, 4
Tropical winds	Troposphere	[c]0.5–3 hr [c]0.5–3 hr [c]0.5–3 hr	100 × 100 km 100 × 100 × 3.5 km 10 × 10 km	2 m/sec 0.5 m/sec 2 m/sec		Sondes, motion detection, submillimeter Lidar Lidar	1, 4
Extratropical winds	Troposphere	[c]0.5–3 hr [c]0.5–3 hr [c]0.5–3 hr	100 × 100 km 100 × 100 × 3.5 km 10 × 10 km	2 m/sec 0.5 m/sec 2 m/sec		Sondes, submillimeter Lidar Lidar	1, 4
Tropospheric water vapor	Troposphere	1–3 hr	100 × 100 km × 100 mbar	0.001 ppm		Sondes, microwave (22 and 183 GHz), IR, lidar	1, 4
Precipitation	Earth surface	[c]0.5–3 hr	1 km	5%	In situ	IR, microwave, radar (37 GHz)	1, 4

Footnotes are at end of table, page 116.

Table I. Continued

Measurement	Location	Temporal resolution	Spatial resolution	Accuracy required	Comments	Measurement method (a)	Source (b)
Earth radiation budget:	Earth disk	[c]1–3 hr	10–30 km	2%			1, 4
long (1–15 μm)						IR	
short (0.3–1 μm)						Visible	
Clouds:						IR: spectrometry, emission, submillimeter	1, 4
extent, type, height	Earth disk	[c]1–3 hr	1 × 1 km	2%	In situ		
emission temperature		6 hr	1 × 1 km	0.5°C			
albedo		6 hr	50 × 50 km	0.01			
H_2O content		6 hr	50 × 50 km	.05 kgm/m2			
pH of rain and clouds		[c]1–3 hr	1 × 1 km				2, 3, 4
Cloud motion	Troposphere	3–5 min	0.5 km			Visible	4
Lightning	Troposphere	3–5 min	0.5 km			0.774 nm	4
Convective stability	Troposphere	15 min	40 km			Microwave	4, 5
Convective storms	Troposphere	1–15 min	0.5 km			Visible, IR	4, 5
Hurricanes	Troposphere	15 min	1–30 km			Visible, mid IR, microwave	4, 5
Fog	Troposphere/ Surface	30 min	0.5 km			Visible, mid IR	4
Dust storms	Troposphere/ Surface	15–60 min	1–10 km			IR	4
Tropospheric aerosols	Troposphere	[c]1–12 hr	10 × 10 × 1 km	5%	In situ	Visible, IR spectrometry, lidar	1, 4
Surface radiating temperature:							1
land	Surface	1–3 hr	1 km	0.5°C		Thermal IR, microwave radiometers	
inland waters	Surface	1–3 hr	30 m	0.1°C		Thermal IR, microwave radiometers	
ice	Surface	1–3 hr	1 km	0.5°C		IR	

Footnotes are at end of table, page 116.

Table I. Continued

Measurement	Location	Temporal resolution	Spatial resolution	Accuracy required	Comments	Measurement method (a)	Source (b)
Incident solar flux	Surface	1 day	100 × 100 km		In situ possible	Visible	1
Snow cover	Continent	1–7 days	30 m–10 km	5%	In situ possible	Visible and IR imaging spectrometers and radiometers, microwave radiometers, SAR (L-, C-, X-, K-bands)	1
Snow water equivalent	Watersheds	0.5–7 days	30 m–1 km	5%	In situ possible	Microwave radiometer (6–91 GHz)	1
Ice sheet volume	Continent	1–50 years	1 km to 100 × 100 km	1%		Laser altimeter, aircraft SAR	1
River runoff (volume)	100s km	1 day	1 km	10%	In situ possible	Visible and IR imaging spectrometers and radiometers, microwave radiometers	1
River flooding	Surface	60 min	0.1–0.5 km			Visible, mid-IR	4
River runoff (sediment loading)	100s km	[c]1–24 hr	0.2–1 km	10%	In situ possible	Visible and IR imaging spectrometers and radiometers, microwave radiometers	1, 4
River runoff (chemical constituents)	100s km	1 day	500 m	10%	In situ possible	Visible and IR imaging spectrometers and radiometers, microwave radiometers	1
Surface characteristics: surface roughness albedo	100s km to continent	1 year 1 day	30 m–1 km 100 × 100 km	10% 1%	In situ possible	Visible, IR, microwave, radar SAR (P-, L-, C-, X-bands) UV to 50 μm	1

Footnotes are at end of table, page 116.

Table I. Continued

Measurement	Location	Temporal resolution	Spatial resolution	Accuracy required	Comments	Measurement method (a)	Source (b)
Index of land use changes	kms to continent	1 day	30 m–1 km	1%	In situ possible, high resolution	Visible and IR imaging spectrometers, SAR	1, 4
Index of vegetation cover (identification and extent)	kms to continent	3–30 days	30 m–1 km	1%	In situ resolution	Visible and IR imaging spectrometers (0.4–2.45 μm), SAR (P-, L-, C-, X-bands)	1, 4
Index of surface wetness (wetlands/irrigation)	kms to continent	2 days	1–10 km	5%	In situ possible	Microwave radiometers (1.4 and 6 GHz), SAR (P-, L-, C-bands)	1, 4
Vegetation stress	kms to continent	1 day	5 km	10%		Imaging spectrometer	2, 3
Soil moisture	kms to continent	12 hrs–3 days	30 m–10 km	5%	In situ	Microwave radiometers	1
Soil type/illumination	Earth surface	30 min	0.1–0.3 km			Visible	4
Biome extent, productivity, and nutrient cycling	kms to continent	3–7 days	30 m–1 km	10%	In situ possible	Visible and IR imaging spectrometers (0.4–2.45 μm), SAR (L-, C-, X-bands)	1
Biomass burning	Troposphere/ Surface		0.5 km			Visible	2,4
Evapotranspiration	Surface	1 day	1 km	5%		IR, visible	2,4
Land surface elevation	Continent	10 years	300 × 300 m	1 m		Laser altimeter, radar altimeter	1
Sea surface temperature	Ocean basins	6 hours	1–4 km	0.1°C	In situ possible	Visible and IR imaging spectrometers and radiometers, microwave radiometers	1
Sea ice extent	Polar oceans	1 week	5–20 km	10 km		Microwave radiometers (18–91 GHz), SAR (L-, C-, X-bands)	1
Sea ice type	Polar oceans	2 weeks	1 km	1%	In situ possible	Microwave radiometers (18–91 GHz), SAR (P-, L-, C-, X-, Ku-bands)	1

Footnotes are at end of table, page 116.

Table I. Continued

Measurement	Location	Temporal resolution	Spatial resolution	Accuracy required	Comments	Measurement method (a)	Source (b)
Sea ice motion	Polar oceans	1 day	100 m	10 m		Surface drifters, radar altimeter, SAR	1
Ocean wind stress	Ocean basins	1 day	50 × 50 km	0.5 m/s	In situ possible	Microwave: scatterometer, altimeter, SAR	1
Ocean wave height	Ocean basins	3 days	50 km	10%		Altimetry	1
Ocean wave spectrum	Ocean basins	3 days	50 km	±10°		SAR	1
Sea level (coastal flooding and shoreline changes)	Ocean basins Shoreline Shoreline	2 days 60 min hrs–weeks	10 km 0.1 km 50–100 m	1 cm	Tide gage	Altimetry Visible, mid IR Visible	1 4 4
Incident solar flux	Global	1 day	100 × 100 km			Visible	1
Subsurface circulation	kms to ocean basins	hrs–days	30 m–100 km	2–20 cm/s	In situ possible	Buoys, altimetry	1
Ocean chlorophyll	kms to ocean basins	2 days	30 m–4 km	10%	In situ possible, 5–10 nm spectral resolution up to 0.7 μm	Imaging spectrometers: (0.435–0.565 μm)	1
Phytoplankton spectra	kms to ocean basins	2 days	30 m–4 km	10%		Visible, IR	2
Biogeochemical fluxes	Global	2 days	30 m–4 km	10%	In situ possible	Visible and IR spectrometers, SAR	1
Ecosystem stress	Global	hrs–days	30–100 m			Visible, IR	4
Ocean CO_2	Ocean basins	2 days	500 m		In situ possible	IR (3 μm)	1
Ocean productivity	Ocean basins	15–60 min	0.2–1 km			400–900 nm	4
Geoid	Global	10 years	1 km	1 cm		Altimetry, tracking systems	1

Footnotes are at end of table, page 116.

Table I. Concluded

Measurement	Location	Temporal resolution	Spatial resolution	Accuracy required	Comments	Measurement method (a)	Source (b)
Plate motions	Global	2 months	1–10000 km	0.5 cm		Very long baseline interferometry, laser ranging	1
Plate deformations	kms to continent	2 months	1–10000 km	0.5 cm	In situ possible	Laser ranging and altimetry, GPS, seismic networks linked to spacecraft, visible and SAR imagery	1
Polar motion and Earth rotation	Global	2 months	10–10000 km			Very long baseline interferometry, lunar ranging	1
Time-dependent magnetic field	Global	years	30 × 30 km	0.5 nT	In situ possible	Magnetometer	1
Changes in gravity	Global	years	30 × 30 km	0.5 mgal		Satellite tracking	1

[a] Abbreviations:

FIR	far infrared
GPS	global positioning satellite
IR	infrared
SAR	synthetic aperture radar
UV	ultraviolet

[b] Source of the global change science measurement requirements:

1. The Bretherton Report
2. Additions from the JPL in-house survey
3. Additions from the LaRC in-house survey
4. GPESSC
5. Additions from the GSFC in-house survey

[c] Additional temporal resolution requirements of the Geostationary Platform Earth Sciences Steering Committee (GPESSC)

Table II. Measurement History for the Science Requirements

Measurement	Location	Operational spacecraft	Name	In situ	Planned spacecraft	Name	No measurement (a)	Priority (b)
Solar irradiance	Sun disk	X	ERB					3
UV	Sun disk	X	SBUV					2
Index of volcanic emissions (see aerosols, gases, atmospheric temperature, ocean surface temperature)	Site specific	X	SAGE 2	X	X	SAGE 3		1
CO_2	Troposphere			X	X	TRACER		3
N_2O	Troposphere						X	2
CH_4	Troposphere						X	2
CFM's	Troposphere						X	2
Troposphere O_3	Troposphere			X				2
Troposphere CO	Troposphere	X	MAPS		X	TRACER		2
Troposphere COS	Troposphere						X	2
Troposphere H_2O	Troposphere			X	X	LASA		2
Troposphere H_2O_2	Troposphere						X	3
Troposphere NO	Troposphere						X	3
Troposphere NO_2	Troposphere						X	3
Troposphere HNO_3	Troposphere						X	3

Footnotes are at end of table, page 125.

Table II. Continued

Measurement	Location	Operational spacecraft	Name	In situ	Planned spacecraft	Name	No measurement (a)	Priority (b)
Troposphere NH_3	Troposphere						X	3
Troposphere C_2H_6	Troposphere						X	3
Troposphere C_2H_2	Troposphere						X	3
Troposphere SO_2	Troposphere	X	SBUV	X				3
Troposphere OH	Troposphere						X	3
Stratosphere O_3	Stratosphere	X	SBUV/TOMS, LIMS, SAGE 2, SME	X	X	GOMR, MLS, ISAMS, CLAES, SAFIRE, HALOE, SAGE 3, LASA		3
Stratosphere H_2O	Stratosphere	X	LIMS, SAGE 2		X	ISAMS, CLAES, SAFIRE, HALOE, SAGE 3		2
Stratosphere NO_2	Stratosphere	X	SAGE 2 SME LIMS		X	SAGE 3, HALOE, ISAMS, CLAES, ATMOS, SAFIRE		1
Stratosphere HNO_3	Stratosphere	X	LIMS	X		ISAMS, CLAES, SAFIRE		1
Stratosphere HCl	Stratosphere	X	ATMOS	X	X	ATMOS, HALOE, CLAES, SAFIRE		1
Stratosphere aerosols	Stratosphere	X	SAM 2, SAGE 2	X	X	SAGE 3, LITE		2
Stratosphere O	Stratosphere				X	SAFIRE		3

Footnotes are at end of table, page 125.

Table II. Continued

Measurement	Location	Operational spacecraft	Name	In situ	Planned spacecraft	Name	No measurement (a)	Priority (b)
Stratosphere O_2	Stratosphere						X	2
Stratosphere CO	Stratosphere	X	MAPS, SAMS		X	TRACER, ISAMS		2
Stratosphere HOCl	Stratosphere				X	SAFIRE		3
Stratosphere OClO	Stratosphere						X	3
Stratosphere OH	Stratosphere				X	SAFIRE		3
Stratosphere HO_2	Stratosphere				X	SAFIRE		3
Stratosphere H_2O_2	Stratosphere				X	SAFIRE, MLS		3
Stratosphere NO	Stratosphere				X	HALOE, ISAMS		3
Stratosphere N_2O	Stratosphere	X	SAMS		X	HALOE, CLAES, ISAMS		3
Stratosphere N_2O_5	Stratosphere				X	SAFIRE, CLAES		3
Stratosphere ClO	Stratosphere				X	MLS		3
Stratosphere $ClONO_2$	Stratosphere				X	CLAES		3
Stratosphere BrO	Stratosphere						X	3
Stratosphere HBr	Stratosphere				X	SAFIRE		3
Stratosphere CH_4	Stratosphere	X	SAMS		X	ISAMS, CLAES, HALOE, SAFIRE		2
Stratosphere CFM's	Stratosphere				X	CLAES		2

Footnotes are at end of table, page 125.

Table II. Continued

Measurement	Location	Operational spacecraft	Name	In situ	Planned spacecraft	Name	No measurement (a)	Priority (b)
Troposphere temperature	Troposphere	X	GOES, TOVS	X	X	AMSU		3
Stratosphere temperature	Stratosphere	X	MSU, ATMOS, LIMS	X	X	AMSU, CLAES, ISAMS, GOMR, SAFIRE		2
Surface pressure	Earth surface						X	3
Tropical winds	Troposphere	X	GOES	X	X	LAWS		2
Extratropical winds	Troposphere			X	X	LAWS		1
Tropospheric water vapor	Troposphere	X	SSM, VAS	X	X	AMSU, LASA		2
Precipitation	Earth surface	X	GOES, SSM	X	X	AMSR, TRMM		3
Earth radiation budget: long (1–15 μm) short (0.3–1 μm)	Earth disk	X	ERBE		X	CERES		2
Clouds:								
extent, type, height	Earth disk	X	GOES	X				2
emission temperature		X	AVHRR					2
albedo		X	GOES					2
H_2O content							X	2
pH of rain and clouds							X	2
Cloud motion	Troposphere	X	GOES					2
Lightning	Troposphere	X	LANDSAT					1

Footnotes are at end of table, page 125.

Table II. Continued

Measurement	Location	Operational spacecraft	Name	In situ	Planned spacecraft	Name	No measurement (a)	Priority (b)
Convective stability	Troposphere	X	GOES	X				1
Convective storms	Troposphere	X	GOES	X				1
Hurricanes	Troposphere	X	GOES	X				1
Fog	Troposphere/ Surface			X				1
Dust storms	Troposphere/ Surface	X	GOES	X				1
Tropospheric aerosols	Troposphere	X	AVHRR	X	X	MODIS, LASA		1
Surface radiating temperature:								
land	Surface	X	AVHRR, VAS					1
inland waters	Surface	X	AVHRR, VAS					1
ice	Surface	X	AVHRR					1
Incident solar flux	Surface	X	GOES					1
Snow cover	Continent	X	AVHRR, SSM		X	AMRIR, AMSR, SAR		1
Snow water equivalent	Watersheds	X	SSM		X	AMSR		1

Footnotes are at end of table, page 125.

Table II. Continued

Measurement	Location	Operational spacecraft	Name	In situ	Planned spacecraft	Name	No measurement (a)	Priority (b)
Ice sheet volume	Continent			X	X	GLRS		1
River runoff (volume)	100s km			X				1
River flooding	Surface			X				1
River runoff (sediment loading)	100s km			X				1
River runoff (chemical constituents)	100s km			X				1
Surface characteristics: surface roughness albedo	100s km to continent	X	AVHRR, SSM, SAR		X	MODIS, SAR		1
Index of land use changes	kms to continent	X	AVHRR, SPOT		X	SAR		2
Index of vegetation cover (identification and extent)	kms to continent	X	AVHRR		X	SAR		3
Index of surface wetness (wetlands/irrigation)	kms to continent	X	SSM		X	SAR		1
Vegetation stress	kms to continent			X				1
Soil moisture	kms to continent	X	AVHRR, GOES, SSM		X	SAR		3
Soil type/illumination	Earth surface	X	SPOT					1

Footnotes are at end of table, page 125.

Table II. Continued

Measurement	Location	Operational spacecraft	Name	In situ	Planned spacecraft	Name	No measurement (a)	Priority (b)
Biome extent, productivity, and nutrient cycling	kms to continent			X	X	SAR		3
Biomass burning	Troposphere/ Surface	X	SPOT					3
Evapotranspiration	Surface						X	3
Land surface elevation	Continent				X	GLRS		2
Sea surface temperature	Ocean basins	X	AVHRR, SSM		X	AMRIR		3
Sea ice extent	Polar oceans	X	SSM		X	SAR		2
Sea ice type	Polar oceans				X	AMSU, SAR		1
Sea ice motion	Polar oceans			X	X	SAR		1
Ocean wind stress	Ocean basins	X	SSM		X	SAR		3
Ocean wave height	Ocean basins				X	GLRS		3
Ocean wave spectrum	Ocean basins				X	SAR		3

Footnotes are at end of table, page 125.

Table II. Continued

Measurement	Location	Operational spacecraft	Name	In situ	Planned spacecraft	Name	No measurement (a)	Priority (b)
Sea level (coastal flooding and shoreline changes)	Ocean basins Shoreline Shoreline			X				2
Incident solar flux	Global	X	GOES					1
Subsurface circulation	kms to ocean basins			X				3
Ocean chlorophyll	kms to ocean basins	X	CZCS		X	MERIS		3
Phytoplankton spectra	kms to ocean basins			X				2
Biogeochemical fluxes	Global				X	SAR		2
Ecosystem stress	Global						X	1
Ocean CO_2	Ocean basins						X	2
Ocean productivity	Ocean basins						X	2
Geoid	Global				X	GLRS		3
Plate motions	Global			X	X	GLRS		2
Plate deformations	kms to continent	X	SPOT		X	GLRS		3

Footnotes are at end of table. page 125.

Table II. Concluded

Measurement	Location	Operational spacecraft	Name	In situ	Planned spacecraft	Name	No measurement (a)	Priority (b)
Polar motion and Earth rotation	Global			X				1
Time-dependent magnetic field	Global				X	GREM		1
Changes in gravity	Global	X	LAGEOS					1

[a]X denotes no existing routine operational measurement
[b]Priority of measurement:

3. Essential
2. Highly important
1. Substantially important

Table III. Technology Readiness Levels

Readiness Level	Definition
1	Basic principles observed and reported
2	Conceptual design formulated
3	Conceptual design tested analytically or experimentally
4	Critical functions/characteristics demonstrated
5	Component/breadboard tested in relevant environment
6	Prototype engineering model tested in relevant environment
7	Engineering model tested in space
8	Full operational capability (incorporated in production design)

Table IV. Work Breakdown Structure (WBS) Proposed for the Global Change Technology Initiative (GCTI)

1.0 Observation thrust

- 1.1 Coolers
- 1.2 Detectors
- 1.3 Submillimeter
- 1.4 Microwave sensing
- 1.5 Optics
- 1.6 Pointing and control
- 1.7 Lasers
- 1.8 Calibration

2.0 Spacecraft and operations thrust

- 2.1 Materials
- 2.2 Structures and control
- 2.3 Systems analysis
- 2.4 Power
- 2.5 Propulsion
- 2.6 Thermal control

3.0 Data and information systems thrust

- 3.1 Systems
- 3.2 Flight element
- 3.3 Information transfer
- 3.4 Ground element

Table V. Summary of LaRC Proposals Submitted to the GCTI

Thrust	No. of quad charts	Proposal funding requirements, millions of dollars					
		FY90	FY91	FY92	FY93	FY94	FY95
1.0 Observation:							
1.1 Coolers	1		0.10	0.10	0.10	0.20	0.20
1.2 Detectors	8	1.53	6.03	8.73	8.73	8.05	4.65
1.3 Submillimeter	0						
1.4 Microwave sensing	8	.90	8.60	12.55	11.70	9.55	5.75
1.5 Optics	9	.98	2.68	4.20	6.50	4.70	1.10
1.6 Pointing and control	3		.90	1.10	2.70	1.50	.70
1.7 Lasers	10	.10	5.95	8.50	11.60	13.20	8.50
1.8 Calibration	1		1.50	1.10	.20	0	0
Subtotal	40	3.51	25.76	36.28	41.53	37.20	20.90
2.0 Spacecraft and operations:							
2.1 Materials	5		4.25	7.90	10.60	11.70	11.15
2.2 Structures and control	2		8.00	10.00	15.50	21.00	15.00
2.3 Systems analysis	6	1.50	10.25	16.20	20.05	46.90	50.90
2.4 Power	1		.20	.25	.20	.25	.25
2.5 Propulsion	2		.35	.30	.35	.45	.20
2.6 Thermal control	2		.35	.35	.50	.60	.40
Subtotal	18	1.50	23.40	35.00	47.20	80.90	77.90
3.0 Data and information systems:							
3.1 Systems	6		3.95	6.55	8.15	5.70	3.50
3.2 Flight element	13	.40	27.30	33.80	45.90	40.50	23.10
3.3 Information transfer	4	1.00	6.30	6.40	7.80	10.30	11.30
3.4 Ground element	1		.50	1.00	1.50	1.50	2.00
Subtotal	24	1.40	38.05	47.75	63.35	58.00	39.90
Grand total	82	6.41	87.21	119.03	152.08	176.10	138.70

Table VI. Traceability of Technologies to Measurement Techniques and Science Requirements

	Technique										LaRC survey		
	Lidar	Gas correlation	UV radiometry	Visible	IR	Far IR	Sub mm	Microwave	Active cavity	In-situ	Horizontal resolution, km	Vertical resolution, km	Accuracy
Observables													
Tropospheric constituents													
Trace gases	√	√			√	√		√		√	500	3.5	10%
Ozone	√			√	√	√		√		√	200	2	10%
Aerosols	√			√	√					√	100	.2	20%
Clouds	√			√	√		√	√		√	1	.1	5%
Middle atmospheric constituents													
Trace gases	√	√			√	√	√	√		√	500	3.5	5%
Ozone	√		√	√	√	√		√		√	200	1	5%
Aerosols	√			√	√					√	200	1	20%
Atmospheric response variables													
Temperature	√				√	√		√		√	300	2	1 K
Pressure	√				√	√		√		√			
Wind*	√						√	√		√	25	3	2 m/s
Precipitation					√			√		√	1		10%
Radiation components*				√	√						100		1%
Solar irradiance*			√						√				
Surface characteristics													
Soil moisture								√		√	10		5%
Vegetation index*				√	√			√		√	1		1%
Biomass burning				√	√						.5		
Volcanoes			√	√	√						1		
Albedo			√	√	√			√			100		1%
Ocean variables													
Temperature				√	√			√		√	1-4		.1°C
Sea ice extent								√			5-20		10 m
Sea level	√										10		1 cm
CO_2 content					√					√	.5		
Plate motions	√										1-1000		.5 cm
Technology needs													
Observation													
Cryogenic cooler technology	√	√			√	√	√	√	√				
Detector technology	√	√	√	√	√	√	√	√	√	√			
Submillimeter technology						√	√			√			
Microwave technology								√		√			
Optical systems technology	√	√	√	√	√	√	√	√	√	√			
Pointing & control technology	√	√	√	√	√	√	√	√	√	√			
Laser system technology	√									√			
Calibration technology	√	√	√	√	√	√	√	√	√	√			
Spacecraft/Operations													
Materials technology	√	√	√	√	√	√	√	√	√				
Structures & control technology	√	√	√	√	√	√	√	√	√	√			
Systems technology	√	√	√	√	√	√	√	√	√				
Power technology	√	√	√	√	√	√	√	√	√				
Propulsion technology													
Thermal systems technology	√	√	√	√	√	√	√	√	√	√			
Data/Information													
Systems technology	√	√	√	√	√	√	√	√	√	√			
Flight processing technology	√	√	√	√	√	√	√	√	√	√			
Information transfer technology	√	√	√	√	√	√	√	√	√	√			
Ground processing technology	√	√	√	√	√	√	√	√	√	√			

* High temporal requirements.

Table VII. Three Phases Proposed in Implementing the GCTI Program

Phase I	EOS technology:
	Cryogenic coolers
	Infrared arrays
	Active microwave
	Submillimeter
	Laser sensing
	Multiinstrument pointing
	Optical communications
	Data visualization
	Access and retrieval
	Information archives
	NDE/NDI
	EOS systems analysis
Phase 2	LEO/GEO technology:
	Microwave sensing
	Power systems
	Propulsion
	Chip level integration
	Optics
	Large array CCD
	Software engineering
	Space environment effects
	Deployable structures
	LEO/GEO system studies
Phase 3	Mission to Planet Earth:
	To be determined

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16. Abstract
The focus of the National Aeronautics and Space Administration's program in remote sensing is primarily Earth system science and the monitoring of Earth global changes. One of NASA's major roles is the identification and development of advanced sensing techniques, operational spacecraft, and the many supporting technologies necessary to meet the stringent science requirements. Langley Research Center has identified the elements of its current and proposed advanced technology development program that are relevant to global change science according to three categories: sensors, spacecraft, and information system technologies. These technology proposals are presented as one-page synopses covering scope, objective, approach, readiness timeline, deliverables, and estimated funding. In addition, the global change science requirements and their measurement histories are briefly discussed.

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