TECHNOLOGY FOR SPACE STATION EVOLUTION
- A WORKSHOP

COMMUNICATIONS AND TRACKING TECHNOLOGY DISCIPLINE

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TECHNOLOGY FOR SPACE STATION EVOLUTION -A WORKSHOP

TECHNOLOGY DISCIPLINE SUMMARY FOR COMMUNICATIONS AND TRACKING

OBJECTIVE:

Develop devices, components, and analytical methods to enhance and enable technology to meet space station evolutionary requirements for multiple access (proximity) communications, space-to-ground communications, and tracking as it pertains to rendezvous and docking as well potential orbital debris warning systems.

SUMMARY:

The Space Station function as the hub of a sophisticated communications network presents significant technical challenges. The multiple access system is required to provide numerous simultaneous links between various spacecraft operating in different zones. Five technology areas have been identified which promise to enable evolutionary performance and safety improvements: optical communications and tracking, monolithic microwave integrated circuit antenna systems, traveling wave tube technology, advanced modulation and coding, and advanced automation for communications and tracking. Several issues have also been identified which deserve careful consideration: debris tracking (safety and operations), frequency allocation (ku-band interference), and higher data rates (user need accomodation).

TECHNOLOGY FOR SPACE STATION EVOLUTION -A WORKSHOP

COMMUNICATIONS AND TRACKING *OPTICAL COMMUNICATIONS AND TRACKING*

BACKGROUND

SCOPE - Accommodation of intra-station data handling requirements, anticipated to be as high as one gigabit per second for certain user payloads, as well as space-to-ground traffic, projected to approach thirty-four terabits per day. Furthermore, the embodiment of a practical system to detect and track orbital debris which is considered to be a potential threat to Space Station integrity.

OBJECTIVES - Provide adequate internal and space-to-ground data handling capability to satisfy user requirements. Capitalize on available high-rate optical fiber technology and develop advanced optoelectronic interface technology. Accelerate development and deployment of optical technology for space applications. Enable graceful evolution of communications architecture to support sophisticated payloads.

REQUIREMENTS - User needs dictate expanded system capability. Real-time data transmission necessitates gigabit-per-second links. Scrub-back procedures have been insensitive to these requirements. Optical technology enables practical high data-rate systems and promises to enable high spatial resolution tracking.

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COMMUNICATIONS AND TRACKING *OPTICAL COMMUNICATIONS AND TRACKING*

PROGRAM PLAN

APPROACH :

1. Exploit small volume and mass, low power requirements, and interference immunity of optical technology to enable a practical high data-rate communication system.
2. Develop optical integrated circuit, optoelectronic interface and system architecture technology for high speed optical fiber links.
3. Develop high power, solid state laser transmitters and high-sensitivity receivers to provide enhanced data rate space-to-ground links.
4. Investigate optical sensor technology for autonomous docking.

DELIVERABLES:

1. Demonstration of low power consumption, gigabit-per-second optical fiber interconnected transmitter/receiver link. (Requires moderate funding option)
2. Demonstration of long-life, high modulation rate, high-power laser transmitters and extremely high sensitivity optical receivers. (Requires high funding option)
3. Conceptualization and analysis of optically guided autonomous rendezvous and docking. (Requires low funding option)
4. Conceptualization and analysis of optical or hybrid optical/millimeter-wave debris tracking system. (Requires low funding option)

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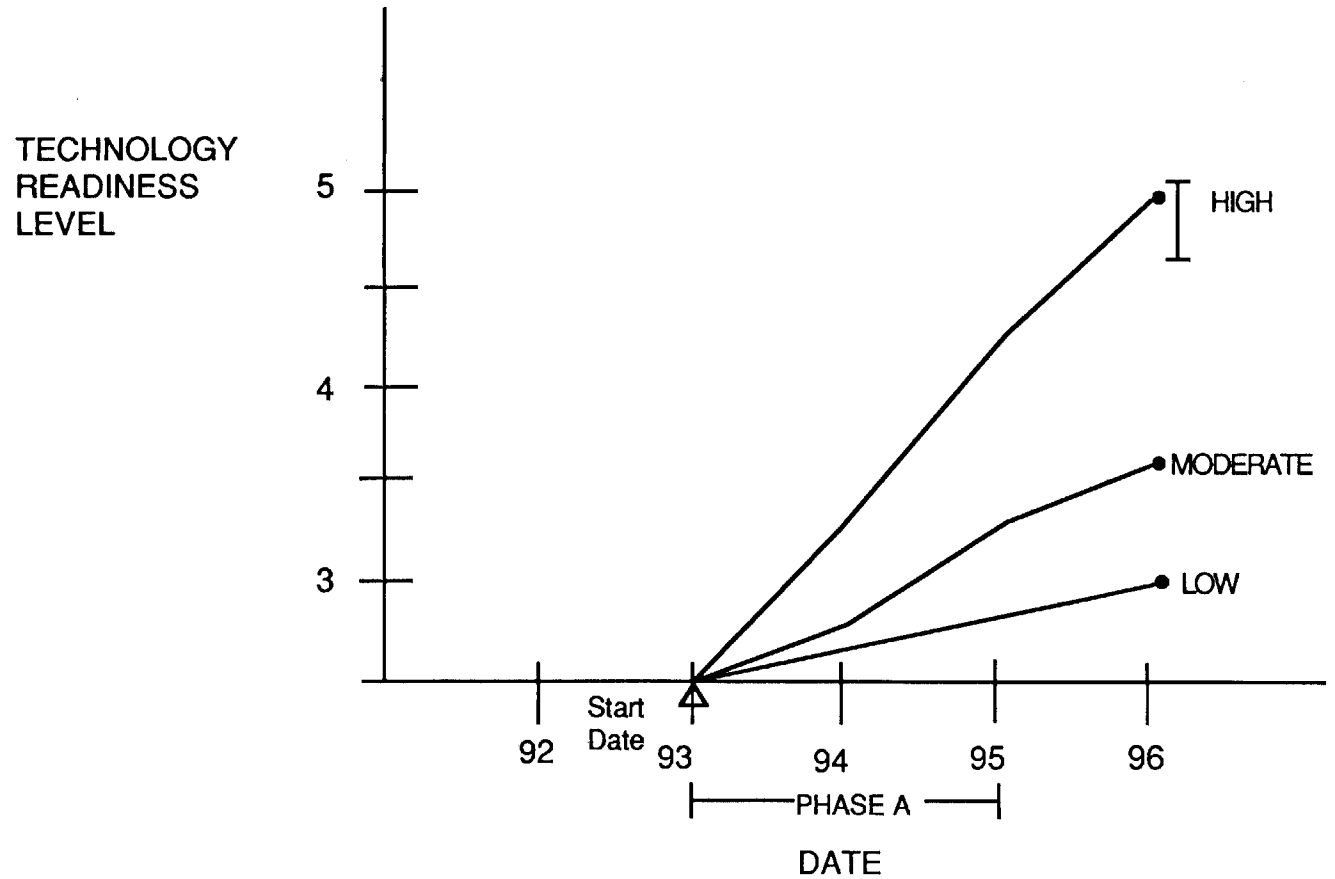
COMMUNICATIONS AND TRACKING *OPTICAL COMMUNICATIONS AND TRACKING*

TECHNOLOGY ASSESSMENT



TECHNOLOGY FOR SPACE STATION EVOLUTION -A WORKSHOP

COMMUNICATIONS AND TRACKING *MONOLITHIC MICROWAVE INTEGRATED CIRCUIT SYSTEMS*

BACKGROUND

SCOPE - Utilization of advanced monolithic microwave integrated circuit (MMIC) technology to provide high-fidelity uninterrupted proximity communications and preemptive orbital debris tracking radar.

OBJECTIVES - Improve versatility and reliability of the multiple-access communications system through the use of active array antennas. Improve confidence and safety of Space Station and station operations through the use of fast scanning rate phased array radar, which is a prerequisite for debris collision avoidance.

REQUIREMENTS - Appreciable interference problems are expected at Ku-band. The eventual transition of Space Station into Ka-band is encouraged by a large constituency. A medium-gain, wide-scan (hemispherical) antenna and a narrow beam scanning phased array antenna for long range (2000 km) operations are candidates for MMIC insertion. The need for power control on return links of the multiple access system has also been identified. Finally, sub-microsecond scanning phased arrays for orbital debris tracking will require millimeter-wave integrated circuit technology.

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COMMUNICATIONS AND TRACKING *MONOLITHIC MICROWAVE INTEGRATED CIRCUIT SYSTEMS*

PROGRAM PLAN

APPROACH:

1. Exploit Ka-band technology to augment data handling capacity and alleviate Ku-band interference problems.
2. Develop manufacturable monolithic integrated circuit amplifiers and phase shifters to enable Ka-band active array antennas.
3. Integrate MMIC technology with compatible antenna technology to produce fast scanning rate arrays for full coverage proximity communications and orbital debris tracking.

DELIVERABLES:

1. Reproducible, cost effective, reliable Ka-band MMIC: variable power (1 W max.) amplifiers, high power (2 to 4 W) amplifiers, and low-loss phase shifters. (Low funding option does not include reliability assessment)
2. Demonstration of two-dimensional fast scanning rate Ka-band phased array antenna. (Requires high funding option)
3. Conceptualization and analysis of on-board millimeter-wave orbital debris tracking system. (Requires moderate funding option)

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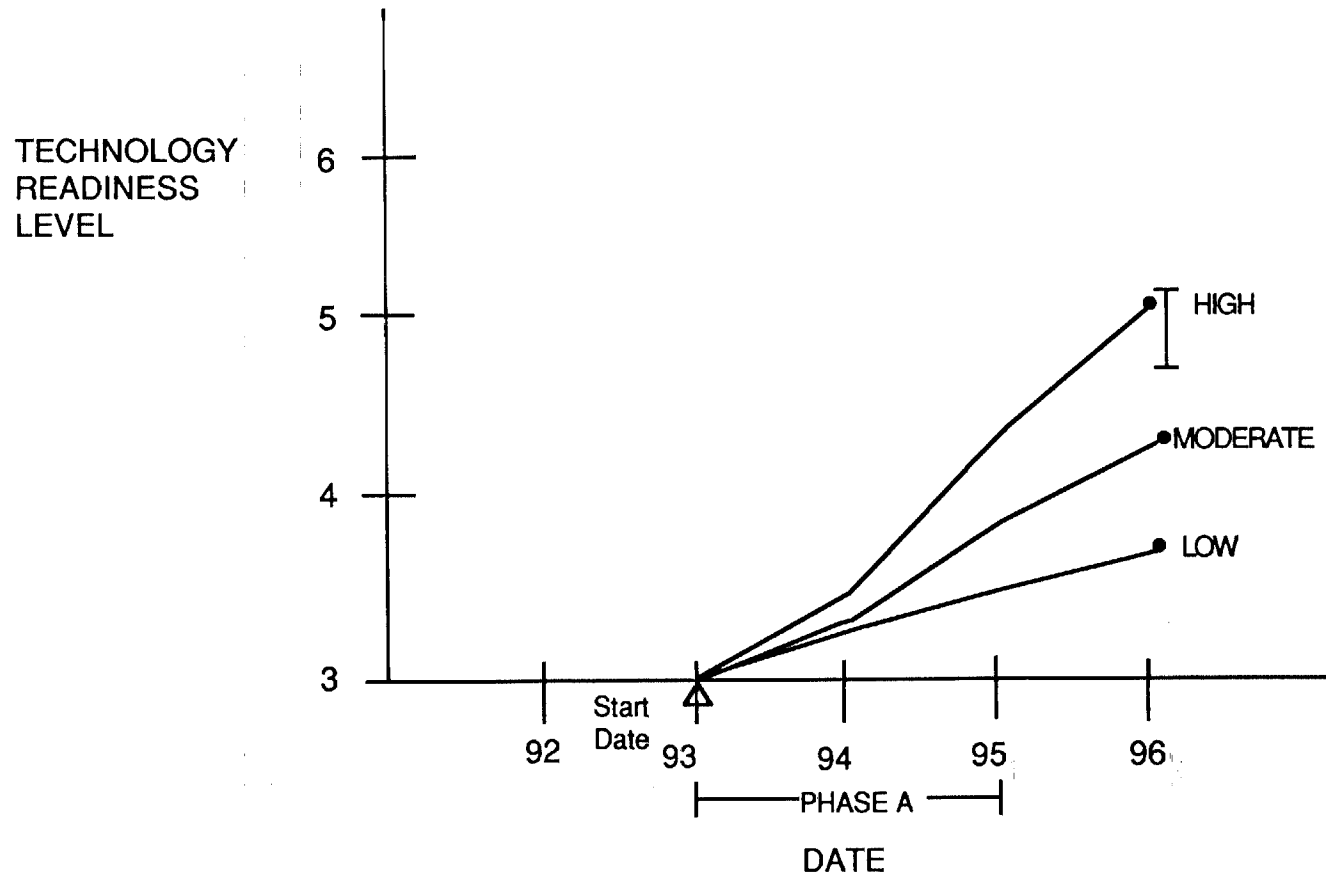
COMMUNICATIONS AND TRACKING *MONOLITHIC MICROWAVE INTEGRATED CIRCUIT ANTENNA SYSTEMS*

TECHNOLOGY ASSESSMENT



TECHNOLOGY FOR SPACE STATION EVOLUTION -A WORKSHOP

COMMUNICATIONS AND TRACKING *TRAVELING WAVE TUBE TECHNOLOGY*

BACKGROUND

SCOPE - Adaptation of proven technology for high data rate (wide bandwidth) link from Space Station Freedom to the Advanced Tracking and Data Relay Satellite System.

OBJECTIVES - Provide low risk, evolutionary communications capability to Space Station. Investigate 60 GHz technology for space-to-space links.

REQUIREMENTS - Existing and anticipated demands on Space Station information handling capability encourage enhanced downlink data rates. ATDRSS is expected to utilize Ka-band architecture; hence, a Ka-band crosslink is a logical evolutionary step. Furthermore, traveling wave tube technology is maturing more rapidly than any competitor at millimeter wavelengths. A 60 GHz traveling wave tube operating with 10% bandwidth, a conservative technical specification, offers a data rate which rivals optical technology.

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COMMUNICATIONS AND TRACKING *TRAVELING WAVE TUBE TECHNOLOGY*

PROGRAM PLAN

APPROACH:

1. Exploit high RF output power, high efficiency, and reliability of traveling wave tube technology to enable adequate data rates for Space Station downlink and develop ATDRSS compatible hardware.
2. Unveil low-risk (near term), moderate-cost alternative to optical communications.
3. Develop 60 GHz traveling wave tube technology for space-to-space communications.

DELIVERABLES:

1. Demonstration of high-power, high-efficiency Ka-band traveling wave tube with appropriate power conditioning peripherals for ATDRSS-type crosslink. (Moderate funding option necessitates relaxed performance and eliminates peripherals)
2. Analysis of prospects, technology readiness, and feasibility of 60 GHz link capability for Space Station Freedom. (Requires moderate funding level)

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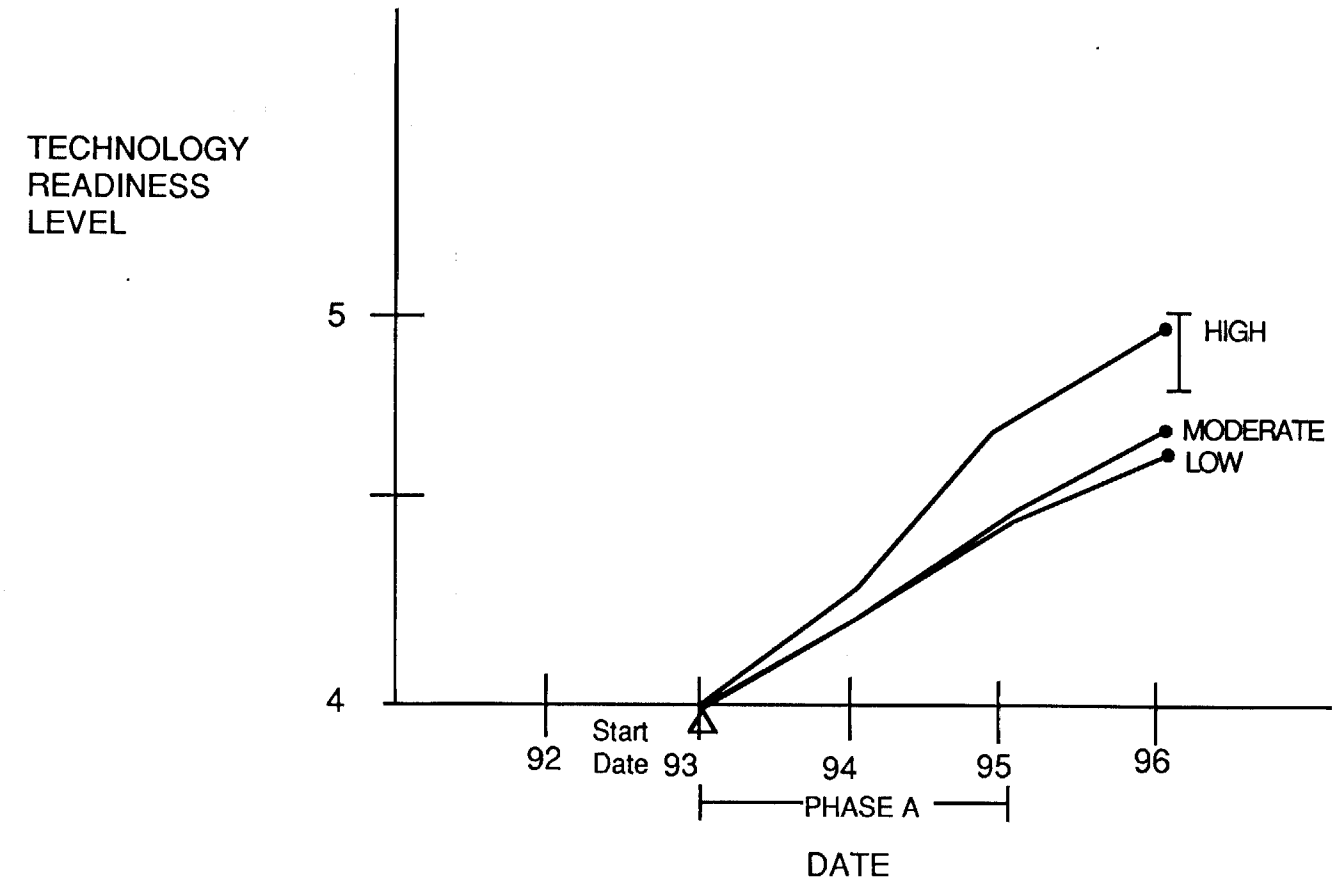
COMMUNICATIONS AND TRACKING

TRAVELING WAVE TUBE TECHNOLOGY

TECHNOLOGY ASSESSMENT



TECHNOLOGY FOR SPACE STATION EVOLUTION -A WORKSHOP

COMMUNICATIONS AND TRACKING

ADVANCED MODULATION AND CODING

BACKGROUND

SCOPE - Expansion of modulation rates using data compression, advanced modulation and coding to provide more efficient use of available bandwidth. Exploration of innovative techniques to reduce information volume to useful data and expand information throughput .

OBJECTIVES - Provide promising alternative or supplement to wider bandwidths through improved spectral utilization (greater than two bits per second per hertz).

REQUIREMENTS - Existing needs and anticipated growth of payload data rates demand an increase in information handling capability. Options include moving to much higher frequencies or enhancing data transmission through existing links. Advanced modulation and coding techniques offer the potential to dramatically reduce the bandwidth required for applications such as high frame rate, high definition television.

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COMMUNICATIONS AND TRACKING *ADVANCED MODULATION AND CODING*

PROGRAM PLAN

APPROACH:

1. Investigate data compression techniques and advanced modulation and coding to exploit available bandwidth as opposed to or in addition to extending Space Station communications operations into millimeter or optical wavelengths to permit greater data throughput, improved bit error rate performance, and enhanced bandwidth efficiency.
2. Develop encoding techniques and modulator/demodulator technology to enable novel bandwidth efficiency improvements.

DELIVERABLES:

1. Analysis and selection of optimum modulation schemes to provide enhanced data rates for intra-Space Station and Space Station-to-ground communication links. (Requires low funding option)
2. Laboratory breadboard demonstration of modulator/demodulator critical functions. (Moderate funding option does not permit parallel approach development)

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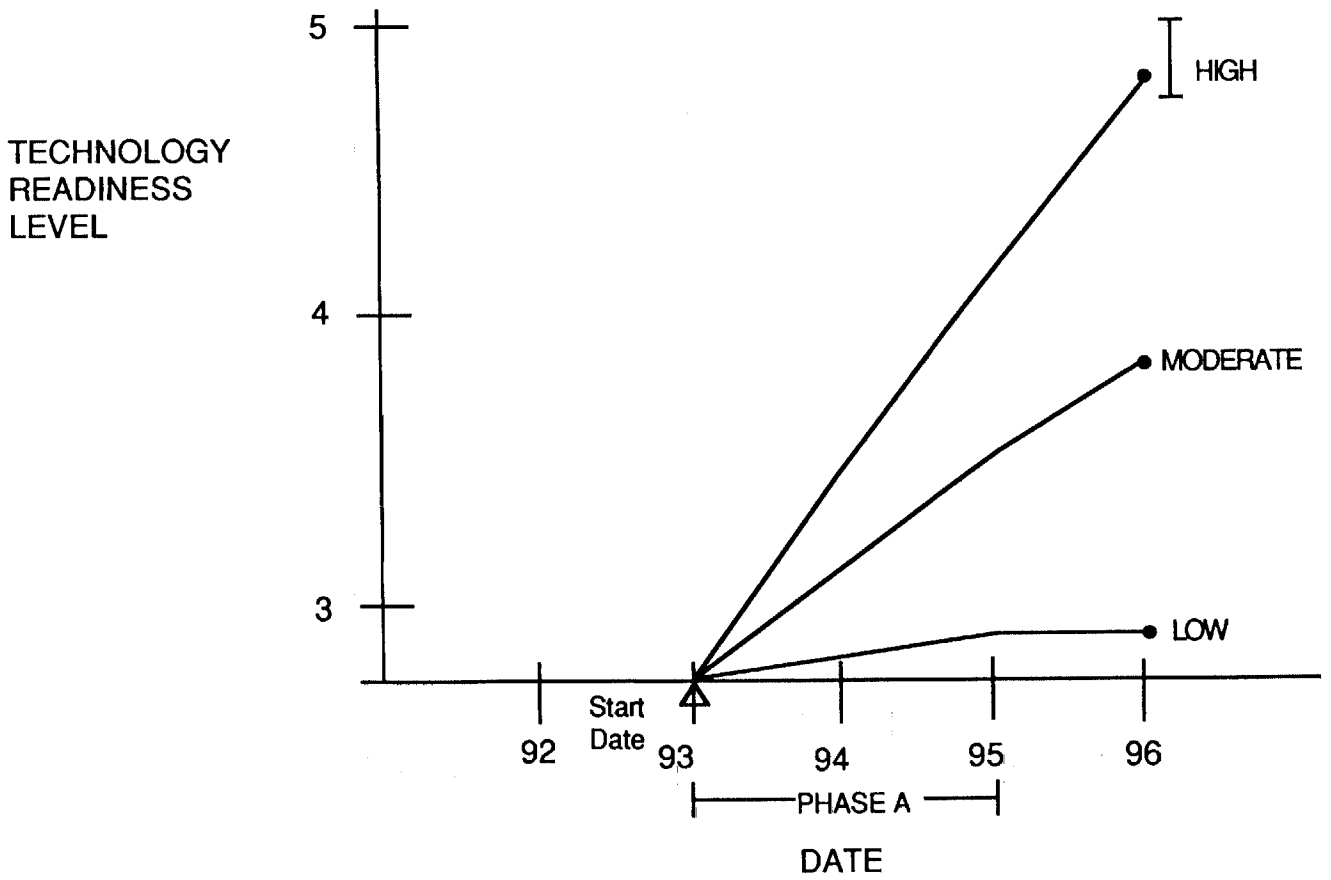
COMMUNICATIONS AND TRACKING

ADVANCED MODULATION AND CODING



TECHNOLOGY FOR SPACE STATION EVOLUTION -A WORKSHOP

COMMUNICATIONS AND TRACKING *ADVANCED AUTOMATION*

BACKGROUND

SCOPE - Implementation of knowledge-based autonomous systems to improve safety and enhance operations of numerous communications and tracking functions.

OBJECTIVES - Identify candidate subsystems likely to benefit from or requiring expert system interaction. Reduce demand on crew time and optimize utilization of communications and tracking resources. Improve safety and reliability of critical operations such as extravehicular activity (EVA). Provide high levels of fault tolerance and diagnostic capability to communications and tracking architecture.

REQUIREMENTS - A plethora of functions and applications dependent on high levels of autonomy for practical implementation exist. Automation is an enabling ingredient for realistic orbital debris tracking and unmanned rendezvous and docking. Numerous communications resource management enhancements are provided as well, especially ground station scheduling and antenna selection. Safe EVA coordination and monitoring could be an early application. A methodical development of expert system integration is essential.

TECHNOLOGY FOR SPACE STATION EVOLUTION -A WORKSHOP

COMMUNICATIONS AND TRACKING *ADVANCED AUTOMATION*

PROGRAM PLAN

APPROACH:

1. Select those communications and tracking systems and operations for which complete or partial autonomy is essential and merge associated functions as a prelude to total expert system integration. For example, optimistically, extravehicular activities, high gain antenna selection, and orbital debris tracking would be coordinated through a central expert system manager.
2. Develop selected fully autonomous expert systems as well as user query/interactive systems for identified functions. Develop appropriate interactive communications environment (speech synthesis, graphics, etc.) to facilitate user interface.
3. Integrate multiple interrelated functions with communications/data management system and user interface system.

DELIVERABLES:

1. Demonstration/simulation of autonomous expert system for selected communications and tracking function.*
2. Demonstration of intelligent user interface for integrated interactive communications and tracking system.*

*(Integration phase requires high funding option, development phase requires moderate funding option, concept phase requires low funding option)

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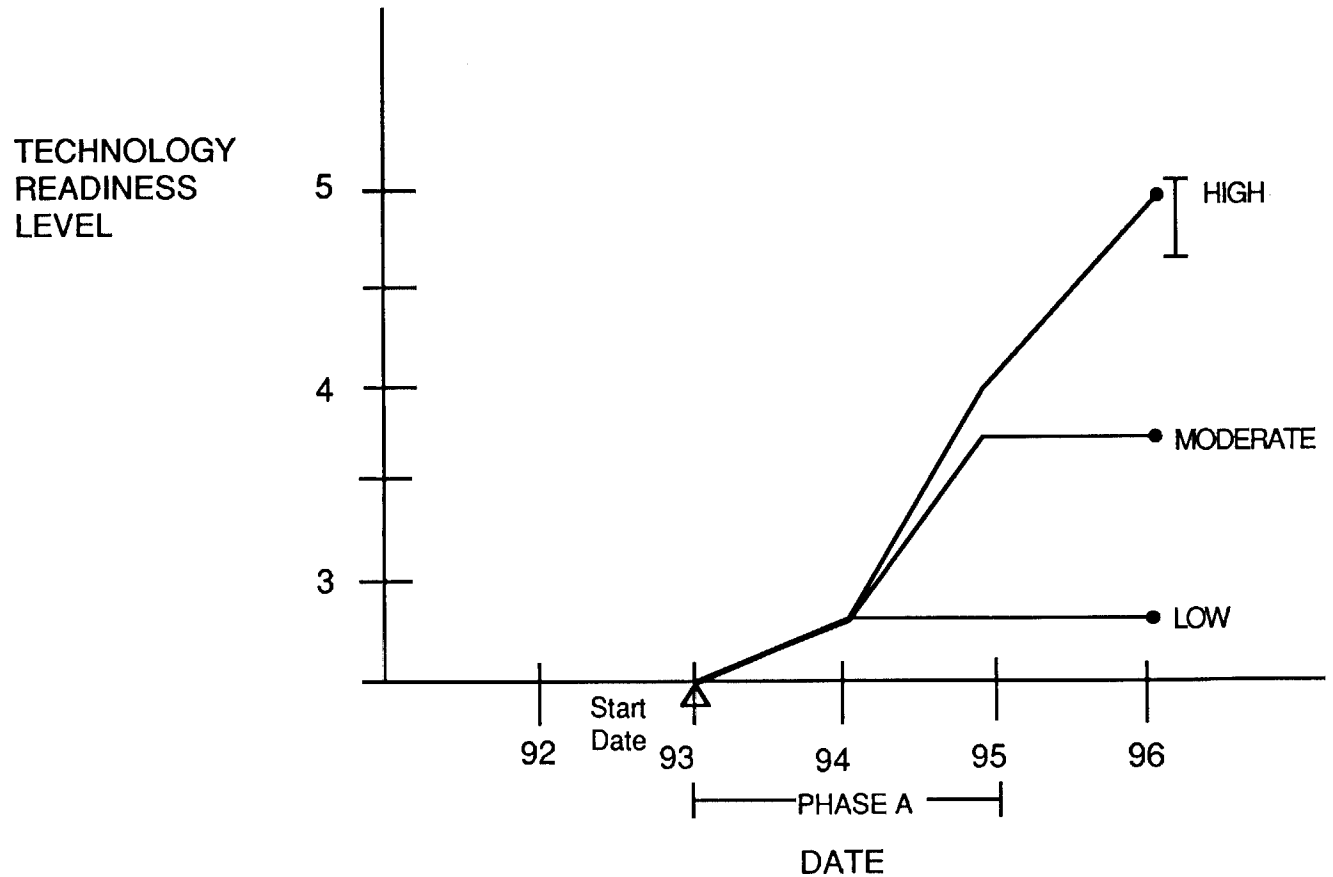
COMMUNICATIONS AND TRACKING

ADVANCED AUTOMATION

TECHNOLOGY ASSESSMENT



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RECOMMENDATIONS/ISSUES FOR COMMUNICATION AND TRACKING

ORBITAL DEBRIS

Orbital debris is considered a significant potential threat to the basic safety of the crew and structure of Space Station. It has been predicted that approximately 50,000 0.1 mm particles will impact Space Station per year. This process will cause continual erosion of surfaces, and could be particularly detrimental to optical instruments and solar panels. Primary concern, however, is focused on the far-from-remote possibility that large particles (greater than 1 cm) will collide with the structure over the projected 30 year lifetime. Although the structure is designed to tolerate collisions with particles having dimensions smaller than 1 cm, it is anticipated that Space Station will experience close encounters with much larger particles every year. Currently, there is no method of tracking debris with dimensions smaller than 10 cm. Ten centimeter and larger particles can be monitored through ground based surveillance. Furthemore, the debris problem is malignant since space activities continue to generate additional material.

RECOMMENDATIONS:

1. Continue/expand (optical/radar) studies of debris distribution
2. Develop precision onboard optical/millimeter wave debris tracking system
3. NASA should pioneer efforts to minimize additional debris

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RECOMMENDATIONS/ISSUES FOR COMMUNICATIONS AND TRACKING

FREQUENCY ALLOCATION

It is expected that the Space Station multiple-access system will experience significant interference at Ku-band. The primary source of interference will be fixed satellite service very small aperture terminals (VSATs), which are expected to proliferate in the 1990's. The nature of interference can range from noisy degradation to momentary blackout. Crew safety could be jeopardized. It is particularly disconcerting that NASA is a secondary user at Ku-band. Consequently, in addition to enduring intermittent interference, potential liability issues exist since Space Station could interfere with primary commercial users. Finally, the possibility of adjacent channel interference with the multiple access system by TDRSS has also been identified due the high sidelobe levels.

RECOMMENDATIONS:

1. Secure Ka-band allocation which designates NASA as primary user
2. Develop necessary Ka-band monolothic microwave integrated circuit and antenna technology.

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RECOMMENDATIONS/ISSUES FOR COMMUNICATIONS AND TRACKING

HIGHER DATA RATES

Intra-Space Station Freedom data rate requirements have been identified which are in excess of planned throughput capacity. For certain user payloads, rates as high as one gigabit/second might be required. Real-time data transmission necessitates much higher rates than currently planned. Retrofitting beyond Assembly Complete (AC) to accomodate growing demands is an untenable solution. Furthermore, optimal payload utilization is encumbered by marginal downlink rate capacity.

RECOMMENDATIONS:

1. Insert high rate fiber for initial Space Station to accomodate existing and anticipated traffic
2. Transition into optical crosslinks and downlinks for advanced TDRS systems
3. Pursue advanced modulation and coding techniques to permit data rate growth