NASA Advanced Information System Technology (AIST) Projections Workshop
9 – 10 January 2002

Sponsored by the Earth Science Technology Office and the NASA HQ Office of Earth Science

The following documents are provided for your information in preparation for the workshop. Hard copies of these documents will be provided at registration:

Workshop results will be posted on the ESTO Web Site http://esto.nasa.gov

AIST Projections Workshop Agenda

Day 1 – Wednesday (9January2002)

Time	
7:30 – 8:30	*Registration, Coffee and Rolls*
8:30 – 8:40	*Welcome and Logistics* (Glenn Prescott, Kortney Stevens)
8:40 – 8:50	*ESTO Welcome* (George Komar)
8:50 – 9:15	*AIST Program Overview* (Steve Smith) (Description of the AIST strategy, overview of the AIST Needs database and the Key Investment Themes)
9:15 – 9:40	*The Earth Science Research Strategy* (Tsengdar Lee) (An overview of the research goals for the Earth Science Enterprise and implications for Information Systems)
9:40 – 10:00	*Technology Projections Workshop Overview* (Karen Moe) (The purpose of workshop. What we hope to accomplish and how the results will be used.)
10:00 – 10:30	*Break* (Refreshments and break into panel sessions)
10:30 – 12:00	*Mission and Data Panels* (Loren Lemmerman, Mike Seablom) (Break into two panels for overview briefing)
12:00 – 1:00	*Lunch*
1:00 – 5:00	*Mission and Data Panels*

Day 2 – Thursday (10January2002)

8:00 – 8:30	*Coffee and Rolls*
8:30 – 12:00	*Mission and Data Panels*
12:00 – 1:00	*Lunch*
1:00 – 2:00	*Assemble Mission-User and Data-User Panel Findings*

Workshop Panel Assignments

AIST January 2002 Workshop
Steve Smith/ESTO
Glenn Prescott/ESTO

Data Users Panel (34)

Lead:
Mike Seablom/GSFC

ESTO:
Karen Moe
Penny Newsome/GST

NASA HQ:
Martha Maiden/YS
Tsengdar Lee/YS

NASA Centers:
Joe Coughlin/Ames
Bruce Barkstrom/LaRC
Steve Hipskind/Ames SOPHIA
Rob Raskin/JPL

GSFC:
Ken McDonald
Gail McConaughy
Matt Schwaller
Vanessa Griffin
Jeanne Behnke
Robin Pfister
Jerry Miller
Julie Breed
David Matusow
Bob Schweiss LDCM

Community:
Sara Graves/UAH
Helen Conover/UAH
Ganesh Gopalan/OSU
Saxon Holbrook/U Montana
Silvia Nittal/U Maine
Yonsook Enloe/SGT
Janet Rountree/SAIC
Tom Milster/U Az
Liping Di/GMU
Ruixin Yang/GMU
Keith Wichmann/GST ECHO
David Isaac/BPS
Mark Maier/Aerospace
Jim Soukup/Aerospace EDC
April Gillam/Aerospace

Mission Users Panel (38)

Lead:
Loren Lemmerman/JPL

ESTO:
Bob Connerton
Kai-Dee Chu/GST

NASA HQ:
John LeBrecque/YS

NASA Centers:
Don Sullivan/Ames SOFIA
Phil Paulsen/GRC
Richard Reinhart/GRC
Kul Bhasin/GRC
William Ivancic/GRC
Bob Bauer/GRC
Carl Mills/LaRC
Amy Walton/JPL
Hamid Hemmati/JPL
Sam Dolinar/JPL
Tien-Hsin Chao/JPL
Walt Brooks/USRA/Ames

GSFC:
Vicki Oxenham
Pen-Shu Yeh
Barbie Medina
Steve Tompkins
Lisa Callahan
Mike Rackley
Tom Flatley
Peter Hughes
Phil Luers
Parminder Ghuman
Dave Everett GPM

Community
Lonnie Welch/Ohio U
Randy Davis/U Col Solar Irradiance
Seamus Tuohy/Draper
Sid Cooke/LM
Mike Goldberg/MitreTec LDCM
Pat Stakem/QSS
Will Rabinovich/NRL
Scott Turner/Aerospace
Pat Cheatham/Aerospace
Keith Scott/MITRE
Joe Harsanyi/ASIT

AIST Needs by Category

This package provides a listing of technology approaches by AIST Needs Category (see Table 1) and associated goal (see Table 2).

Table 1. AIST Needs Categories

Record Number	AIST Needs
7.1	Data Collection
7.2	Transmission
7.3	Data & Information Production
7.4	Analysis, Search & Display
7.5	Systems Management
7.6	Infrastructure

Table 2. AIST Goals

Goal	Description
1	Improved user-centric and mission oriented organization and search of scientific data
2	Improved user-centric and mission oriented extraction and fusion of scientific data
3	Improved user-centric and mission oriented visualization of scientific data
4	Improved data access through metadata interoperability
5	Improved performance, flexibility and adaptability of data processing
6	Collection, storage, retrieval and management of large data volumes
7	Transmission of large data volumes
8	Efficiency of data transmission
9	Ubiquitous communications networks
10	Enable sensor web communications & control needs (constellation & formation flying)
11	Increased autonomous operations & data management for ground & space based systems
12	Improved systems operation and management
13	Improved system interoperability and use of standards
14	Improved reliability of hardware/software
15	Reduced life cycle cost of ground and space based processing

Guidance

1) For each of the existing technology approaches, determine whether that technology approach should be kept as is (keep), deleted (del), or modified (mod). Provide the rationale for those technology approaches for which you recommend deletion or significant modification.
2) For each existing goal, identify any additional (new) technology approaches and provide the rationale for their inclusion.
3) New goals and their constituent technology approach(es) may be added using the blank rows at the bottom of each table. Provide justification for the addition of these new goals and technology approaches.

7.1 Data Collection

Goals and Requirements		Needs Desig-nation	Technology Approaches	Keep Del Mod New
Goal #	Contents			
11	Increased autonomous operations and data management for ground and space based systems	7.1.1	On board processing; More intelligence on board	
		7.1.2	Advanced fault management technologies	
5	Improved performance, flexibility & adaptability of data processing	7.1.3	Adaptive on-board processing; Reprogrammability (reconfigurable computing)	
		7.1.4	High performance processing and on-board high speed bus	
		7.1.5	On board high speed LANs	
6	Collection, storage, retrieval and management of large data volumes	7.1.6	Reduce data volume	
		7.1.7	High density storage on-board	
15	Reduced life cycle cost of ground and space-based processing	7.1.8	Reduce use of special purpose processors	
14	Improved reliability of hardware/software	7.1.9	Increase fault handling; Technologies for testing components on ground	
		7.1.10	Use of standards	

7.2 Transmission

Goals and Requirements		Needs Desig-nation	Technology Approaches	Keep Del Mod New
Goal #	**Contents**			
8	Efficiency of data transmission	7.2.1	On-board high fidelity data compression and error correction techniques	
		7.2.2	Use of semantic content for prioritization of data transmission	
		7.2.3	Direct downlink of user-tailored near real-time products processed on-board	
		7.2.4	Buffer management techniques (e.g. AI)	
7	Transmission of large data volumes	7.2.5	Increase capacity of space to ground links and intersatellite links	
		7.2.6	Increase ground network transmission speed, Leverage state of the art ground network advances and compression	
9	Ubiquitous communication networks	7.2.7	Extend consensus based network protocols to space	
		7.2.8	Seamless space/ground hybrid network protocols and management	

7.3 Data & Information Production

Goals and Requirements		Needs Desig-nation	Technology Approaches	Keep Del Mod New
Goal #	Contents			
12	Improved systems operation and management	7.3.1	Improved data product and workflow management	
5	Improved performance, flexibility and adaptability of data processing	7.3.2	Create a framework supporting execution of interdisciplinary simulation models and data processing algorithms	
		7.3.3	Autonomous update of global data models	
		7.3.4	Automatic code generation of processing algorithms	
1	Improved user-centric and mission oriented organization and search of scientific data	7.3.5	User-optimized (independent of acquisition mode) data/query representation for search, navigation, exploration	
		7.3.6	Exploitation of commercial database technologies	
		7.3.7	Highly-responsive user access (e.g. from hand held wireless personal devices to large modeling and archive facilities)	
6	Collection, storage, retrieval and management of large data volumes	7.3.8	Adaptive high capacity, efficient, reliable and flexible storage.	

7.4 Analysis, Search & Display

Goals and Requirements		Needs Desig-nation	Technology Approaches	Keep Del Mod New
Goal #	**Contents**			
2	Improved user-centric and mission-oriented extraction and fusion of scientific data	7.4.1	Combine knowledge from various sources and types (e.g. raster, vector, point, etc.) for decision making	
		7.4.2	Knowledge and/or data representation to enable fusion with other information at other levels of abstraction	
		7.4.3	Data organization for ease of user access for discovery, query, fusion and extraction	
		7.4.4	Warehousing and data mining of selected data	
		7.4.5	Identification of sets of data that exhibit a sought relationship	
		7.4.6	Use of knowledge features, regions, models, objects, and semantics to detect changes in environment	
3	Improved user-centric and mission-oriented visualization of scientific data	7.4.7	Use of collaborative meeting and visualization tools	
		7.4.8	Human perception visualization optimization	
		7.4.9	Graphical visualization using "best practices" in human perception	
		7.4.10	Knowledge or concept based visualization	

7.4 Analysis, Search & Display (Continued)

Goals and Requirements: Goal #	Contents	Needs Desig-nation	Technology Approaches	Keep Del Mod New
1	Improved user-centric and mission oriented organization and search of scientific data	7.4.11	Human in the loop retrieval/processing using natural language queries/analysis	
		7.4.13	Physical or logical representations of earth science data	
		7.4.14	Web Portal / general use interface to Earth Science data products	
		7.4.15	Maintain algorithm and data/metadata traceability	
		7.4.16	Knowledge management (capture, representation and categorization of Earth Science knowledge)	
5	Improved performance, flexibility and adaptability of data processing	7.4.12	User environment with rich problem solving toolsets (e.g. problem solving environments)	
		7.4.17	Methodologies for measuring earth science search and retrieval response times and network Quality of Service (QoS)	

7.5 Systems Management

Goals and Requirements		Needs Desig-nation	Technology Approaches	Keep Del Mod New
Goal #	Contents			
11	Increased autonomous operations and data management for ground and space based systems	7.5.1	Goal directed science data management (e.g. automatically task sensor web and corresponding ground components to reconfigure for on-demand event or model predictions)	
12	Improved systems operation and management	7.5.2	Enterprise and system management through established methods	
10	Enable sensor web communications and control needs (constellation and formation flying)	7.5.3	Autonomous operations for sensor webs	
		7.5.4	More intelligence on-board and ground (e.g. contingency planning, formation flying, flight-route planning, etc.)	

7.6 Infrastructure

Goals and Requirements		Needs Desig-nation	Technology Approaches	Keep Del Mod New
Goal #	**Contents**			
6	Collection, storage, retrieval and management of large data volumes	7.6.1	Long-term, high density, high access speed archival media and formats including compression for storage	
		7.6.2	Evolvable storage media and formats including storage, archival, and retrieval standards	
		7.6.3	Generational upgrades of data	
		7.6.4	Interarchive retrieval	
		7.6.5	Storage architecture that supports adaptive georeferenced access patterns	
13	Improved system interoperability and use of standards	7.6.6	Middleware, Pluggable computational frameworks, Plug-and-play software components and modules, Framework for pluggable data, algorithms and models	
		7.6.7	Reusable software, Development process including standards and testbeds, Commercial standards and protocols	
		7.6.8	Identify and infuse NASA-specific requirements into commercial standards processes	

7.6 Infrastructure (Continued)

Goals and Requirements		Needs Desig-nation	Technology Approaches	Keep Del Mod New
Goal #	**Contents**			
15	Reduced life cycle cost of ground and space-based processing	7.6.9	Establish reference architectures leveraging commercial and military technologies	
		7.6.10	Develop tools/environments for modeling and simulation	
		7.6.11	Tools supporting shifting functions between ground and satellite	
		7.6.12	Tools and environments to speed development and system test	
		7.6.13	Scalability issues for data fusion (e.g. performance, accuracy, standard representations)	
1	Improved user-centric and mission oriented organization and search of scientific data	7.6.14	Light-weight data management (i.e. leverage web search technologies for geospatial data)	
		7.6.15	Distributed data services standards and protocols (enabling space/ground data processing trades and realtime reconfiguration)	
		7.6.16	Extract and expose content of data in metadata for use as basis of search	
		7.6.17	Support finding data products that were derived from a given source	

7.6 Infrastructure (Continued)

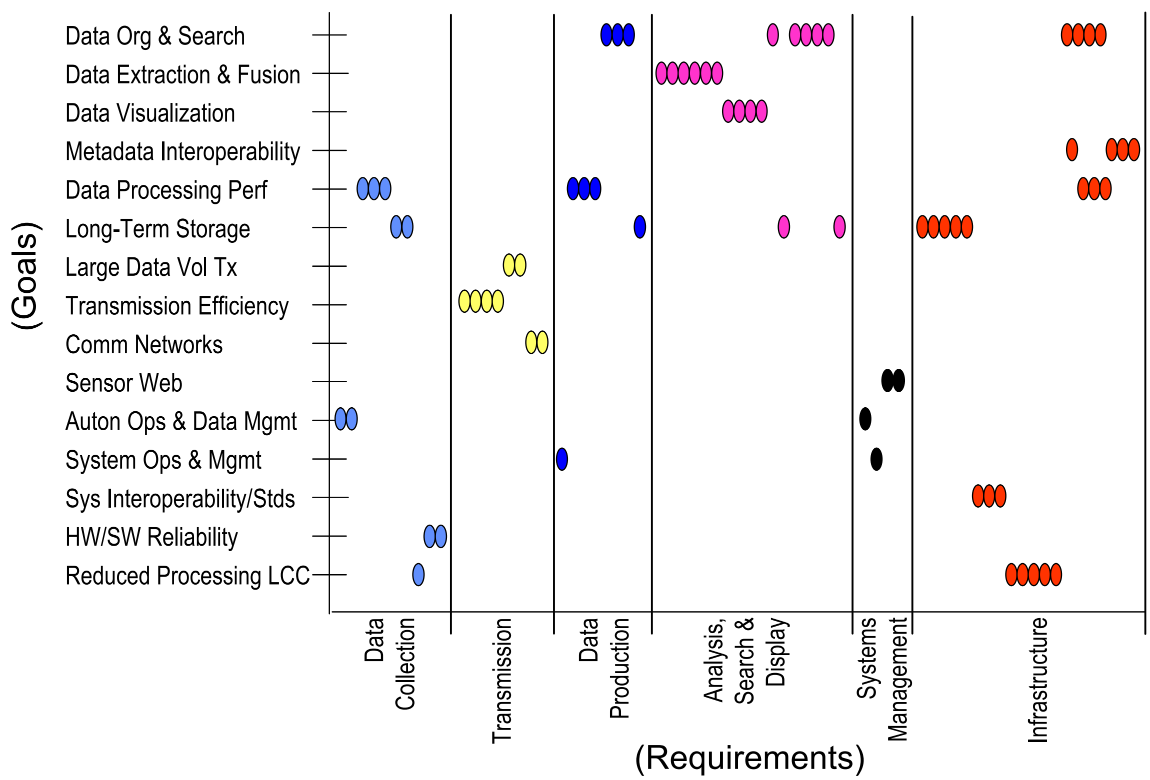
Goals and Requirements		Needs Desig-nation	Technology Approaches	Keep Del Mod New
Goal #	Contents			
4	Improved data access through metadata interoperability	7.6.18	Exploitation of commercial and industry standards	
		7.6.19	Metadata definition and standards (e.g. Markup languages)	
		7.6.20	Shared schemata, Interoperability software tools and metadata for data and services	
		7.6.21	Portable representations of geospatially referenced data	
5	Improved performance, flexibility and adaptability of data processing	7.6.22	Distributed computing	
		7.6.23	High-speed interconnects (e.g. Innovative node connection networks, High performance/pervasive networks)	
		7.6.24	High performance processing (e.g. computing clusters, Reconfigurable computing, embedded computing, optical computing)	

AIST Technology Approaches by Goal

This package provides the context for each of the 15 current AIST goals by identifying the technology approaches (needs) associated with each of the goals. Many goals encompass needs from several AIST Categories. For example, Goal 1 (Improved user-centric and mission oriented organization and search of scientific data) includes needs in the following categories: Data and Information Production; Analysis, Search and Display; and Infrastructure. The chart below provides an overview of the needs associated with each goal.

Guidance

1) For each of the existing goals, determine whether that goal should be kept as is (keep), deleted (del), or modified (mod). Circle the appropriate action in the left-hand column and provide the rationale for those goals for which you recommend deletion or significant modification.
2) Space is provided at the end of this package to identify new goals that may not fit well within the existing needs categories. Document any new goals and constituent technology approaches NOT PREVIOUSLY DOCUMENTED in the "AIST by Needs Category" worksheet here. Provide the rationale for the addition of any new goals and associated technology approaches.



Goal 1: Improved user-centric and mission oriented organization and search of scientific data

Keep Del Mod	
7.3.5	User-optimized (independent of acquisition mode) data/query representation for search, navigation, exploration
7.3.6	Exploitation of commercial database technologies
7.3.7	Highly-responsive user access (e.g. from hand held wireless personal devices to large modeling and archive facilities)
7.4.11	Human in the loop retrieval/processing using natural language queries/analysis
7.4.13	Physical or logical representations of earth science data
7.4.14	Web Portal / general use interface to Earth Science data products
7.4.15	Maintain algorithm and data/metadata traceability
7.4.16	Knowledge management (capture, representation and categorization of Earth Science knowledge)
7.6.14	Light-weight data management (i.e. leverage web search technologies for geospatial data)
7.6.15	Distributed data services standards and protocols (enabling space/ground data processing trades and realtime reconfiguration)
7.6.16	Extract and expose content of data in metadata for use as basis of search
7.6.17	Support finding data products that were derived from a given source

Goal 2: Improved user-centric and mission oriented extraction and fusion of scientific data

Keep Del Mod	
7.4.1	Combine knowledge from various sources and types (e.g. raster, vector, point, etc.) for decision making
7.4.2	Knowledge and/or data representation to enable fusion with other information at other levels of abstraction
7.4.3	Data organization for ease of user access for discovery, query, fusion and extraction
7.4.4	Warehousing and data mining of selected data
7.4.5	Identification of sets of data that exhibit a sought relationship
7.4.6	Use of knowledge features, regions, models, objects, and semantics to detect changes in environment

Goal 3: Improved user-centric and mission oriented visualization of scientific data

Keep Del Mod	
7.4.7	Use of collaborative meeting and visualization tools
7.4.8	Human perception visualization optimization
7.4.9	Graphical visualization using "best practices" in human perception
7.4.10	Knowledge or concept based visualization

Goal 4: Improved data access through metadata interoperability

Keep Del Mod	
7.6.18	Exploitation of commercial and industry standards
7.6.19	Metadata definition and standards (e.g. Markup languages)
7.6.20	Shared schemata, Interoperability software tools and metadata for data and services
7.6.21	Portable representations of geospatially referenced data

Goal 5: Improved performance, flexibility and adaptability of data processing

Keep Del Mod	
7.1.3	Adaptive on-board processing; Reprogrammability (reconfigurable computing)
7.1.4	High performance processing and on-board high speed bus
7.1.5	On board high speed LANs
7.3.2	Create a framework supporting execution of interdisciplinary simulation models and data processing algorithms
7.3.3	Autonomous update of global data models
7.3.4	Automatic code generation of processing algorithms
7.4.12	User environment with rich problem solving toolsets (e.g. problem solving environments)
7.4.17	Methodologies for measuring earth science search and retrieval response times and network Quality of Service (QoS)
7.6.22	Distributed computing
7.6.23	High-speed interconnects (e.g. Innovative node connection networks, High performance/pervasive networks)
7.6.24	High performance processing (e.g. computing clusters, Reconfigurable computing, embedded computing, optical computing)

Goal 6: Collection, storage, retrieval and management of large data volumes

Keep Del Mod	
7.1.6	Reduce data volume
7.1.7	High density storage on-board
7.3.8	Adaptive high capacity, efficient, reliable and flexible storage.
7.6.1	Long-term, high density, high access speed archival media and formats including compression for storage
7.6.2	Evolvable storage media and formats including storage, archival, and retrieval standards
7.6.3	Generational upgrades of data
7.6.4	Interarchive retrieval
7.6.5	Storage architecture that supports adaptive georeferenced access patterns

Goal 7: Transmission of large data volumes

Keep Del Mod	
7.2.5	Increase capacity of space to ground links and intersatellite links
7.2.6	Increase ground network transmission speed, Leverage state of the art ground network advances and compression

Goal 8: Efficiency of data transmission

Keep Del Mod	
7.2.1	On-board high fidelity data compression and error correction techniques
7.2.2	Use of semantic content for prioritization of data transmission
7.2.3	Direct downlink of user-tailored near real-time products processed on-board
7.2.4	Buffer management techniques (e.g. AI)

Goal 9: Ubiquitous communications networks

Keep Del Mod	
7.2.7	Extend consensus based network protocols to space
7.2.8	Seamless space/ground hybrid network protocols and management

Goal 10: Enable sensor web communications and control needs (constellation and formation flying)

Keep Del Mod	
7.5.3	Autonomous operations for sensor webs
7.5.4	More intelligence on-board and ground (e.g. contingency planning, formation flying, flight-route planning, etc.)

Goal 11: Increased autonomous operations and data management for ground and space based systems

Keep Del Mod	
7.1.1	On board processing; More intelligence on board
7.1.2	Advanced fault management technologies
7.5.1	Goal directed science data management (e.g. automatically task sensor web and corresponding ground components to reconfigure for on-demand event or model predictions)

Goal 12: Improved systems operation and management

Keep Del Mod	
7.3.1	Improved data product and workflow management
7.5.2	Enterprise and system management through established methods

Goal 13: Improved system interoperability and use of standards

Keep Del Mod	
7.6.6	Middleware, Pluggable computational frameworks, Plug-and-play software components and modules, Framework for pluggable data, algorithms and models
7.6.7	Reusable software, Development process including standards and testbeds, Commercial standards and protocols
7.6.8	Identify and infuse NASA-specific requirements into commercial standards processes

Goal 14: Improved reliability of hardware/software

Keep Del Mod	
7.1.9	Increase fault handling; Technologies for testing components on ground
7.1.10	Use of standards

Goal 15: Reduced life cycle cost of ground and space based processing

Keep Del Mod	
7.1.8	Reduce use of special purpose processors
7.6.9	Establish reference architectures leveraging commercial and military technologies
7.6.10	Develop tools/environments for modeling and simulation
7.6.11	Tools supporting shifting functions between ground and satellite
7.6.12	Tools and environments to speed development and system test
7.6.13	Scalability issues for data fusion (e.g. performance, accuracy, standard representations)

Goal:

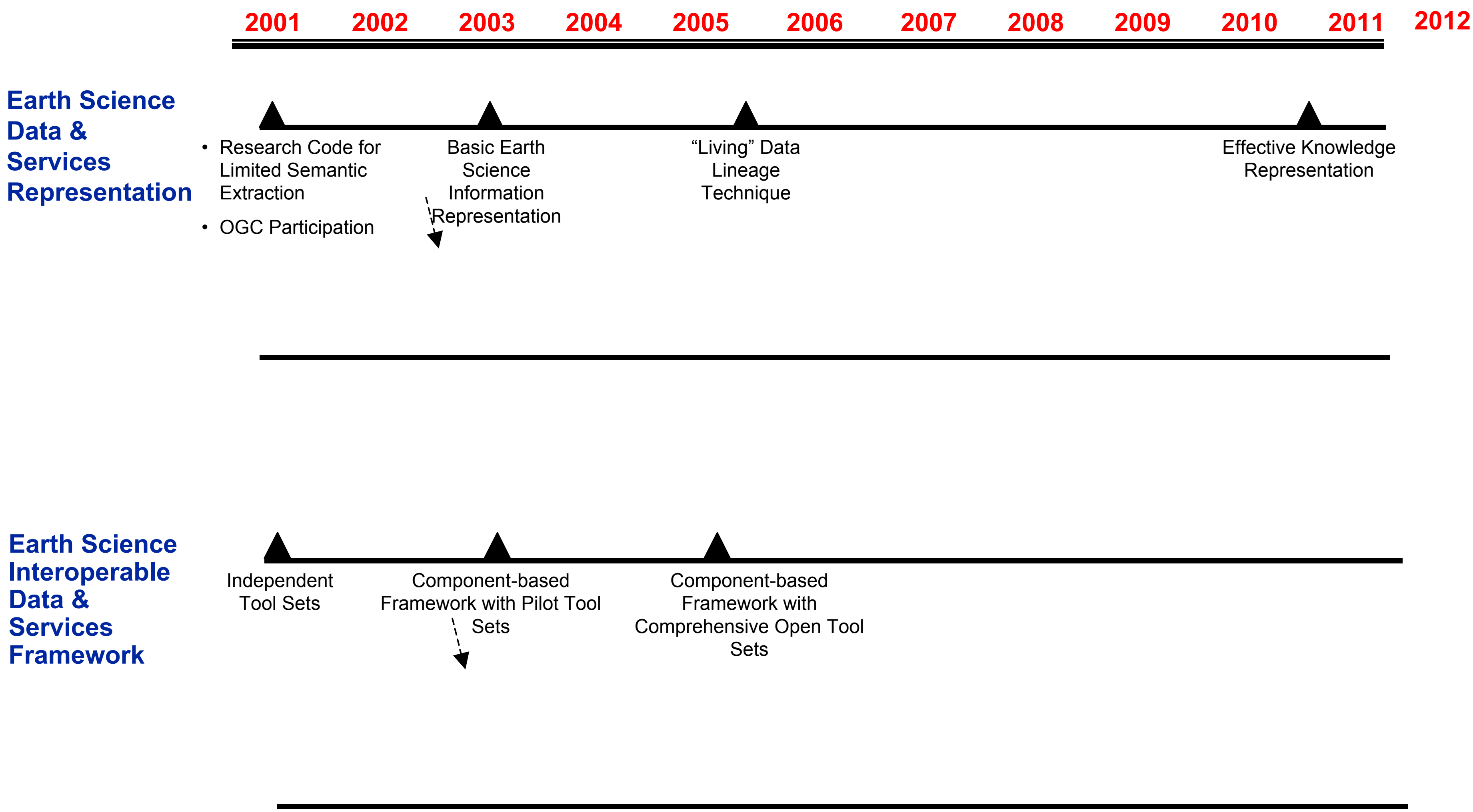
New	

Goal:

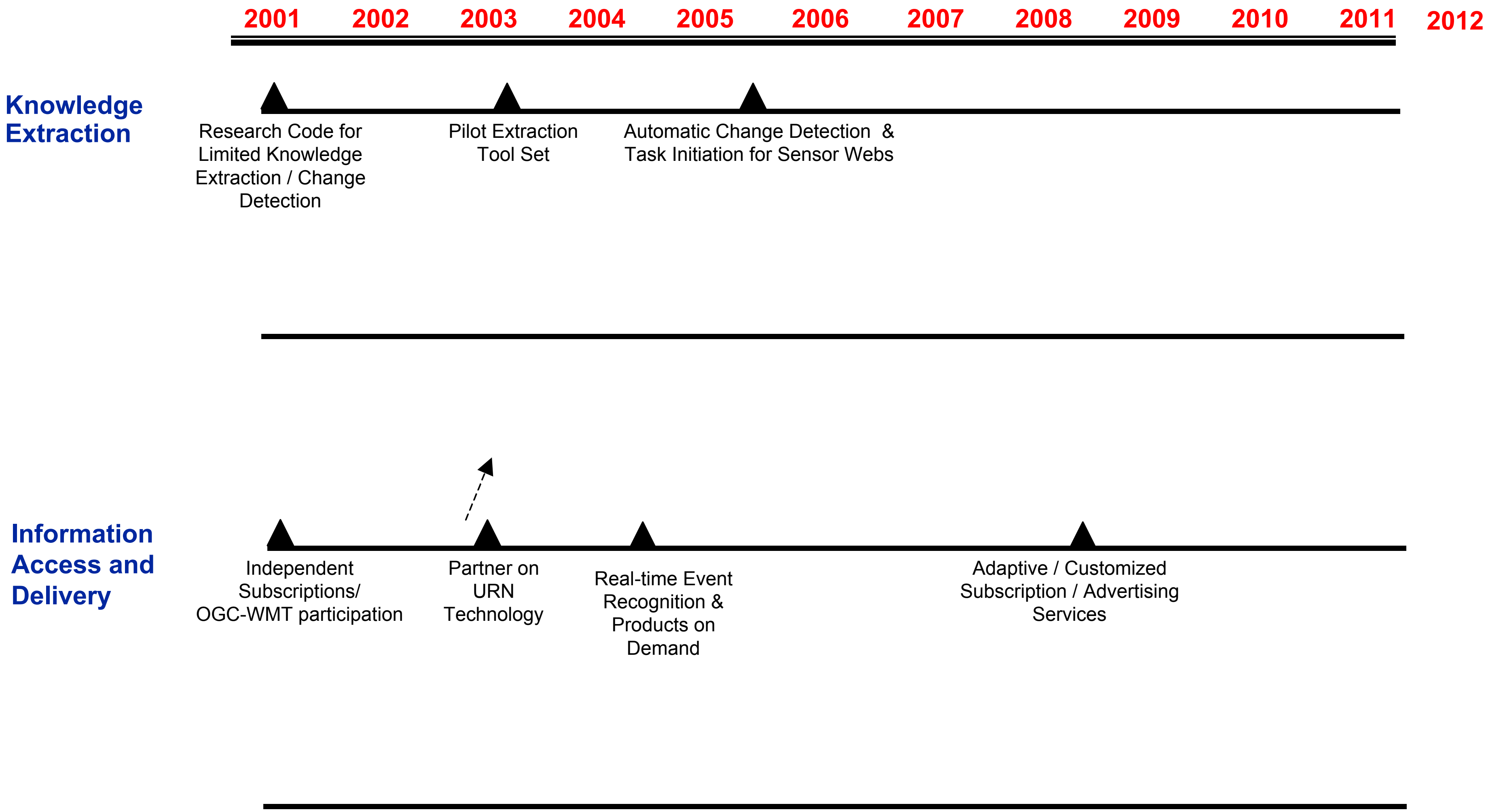
New	

AIST Key Investments Worksheet

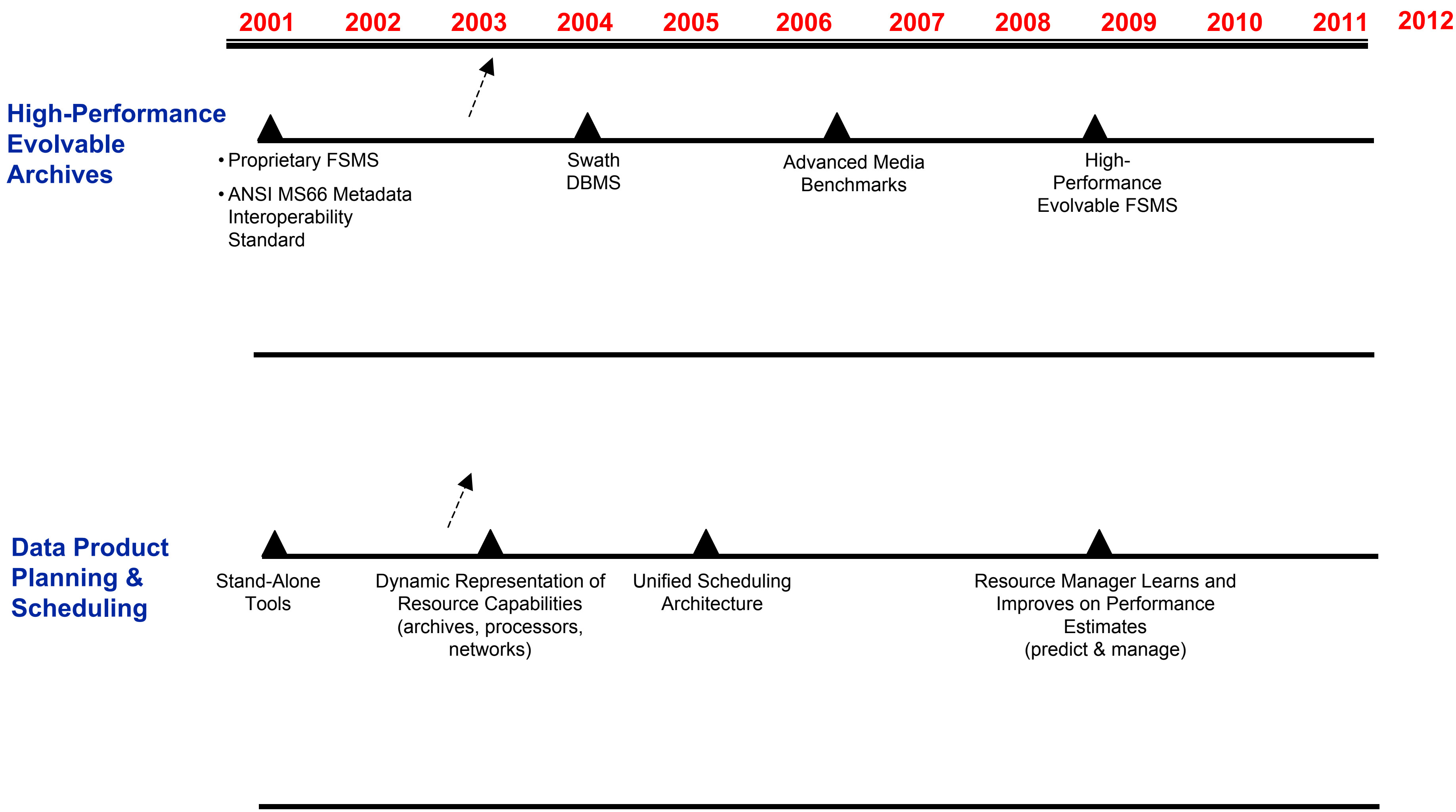
AIST Key "Ground" Investment Themes



AIST Key “Ground” Investment Themes

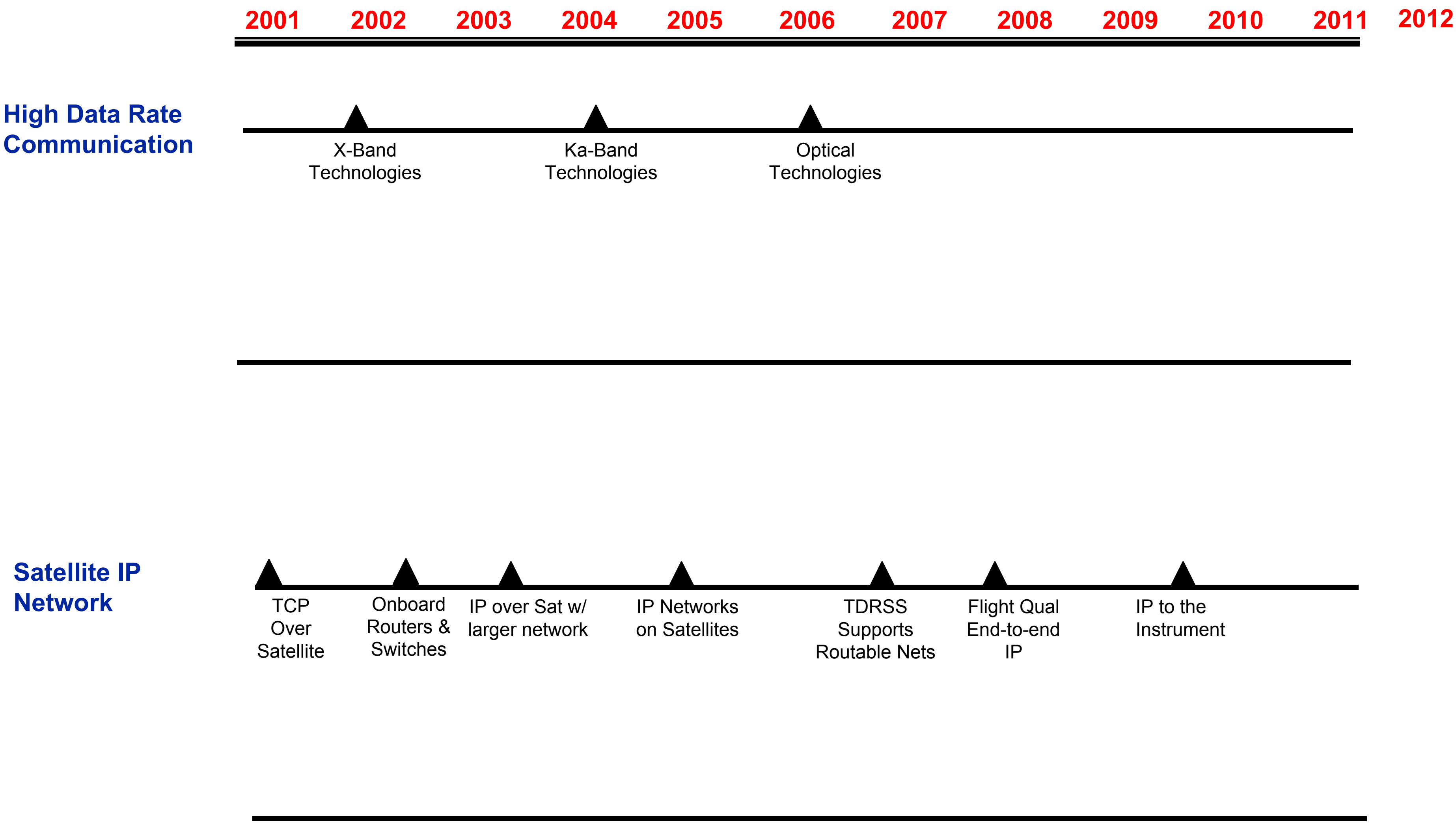


AIST Key "Ground" Investment Themes

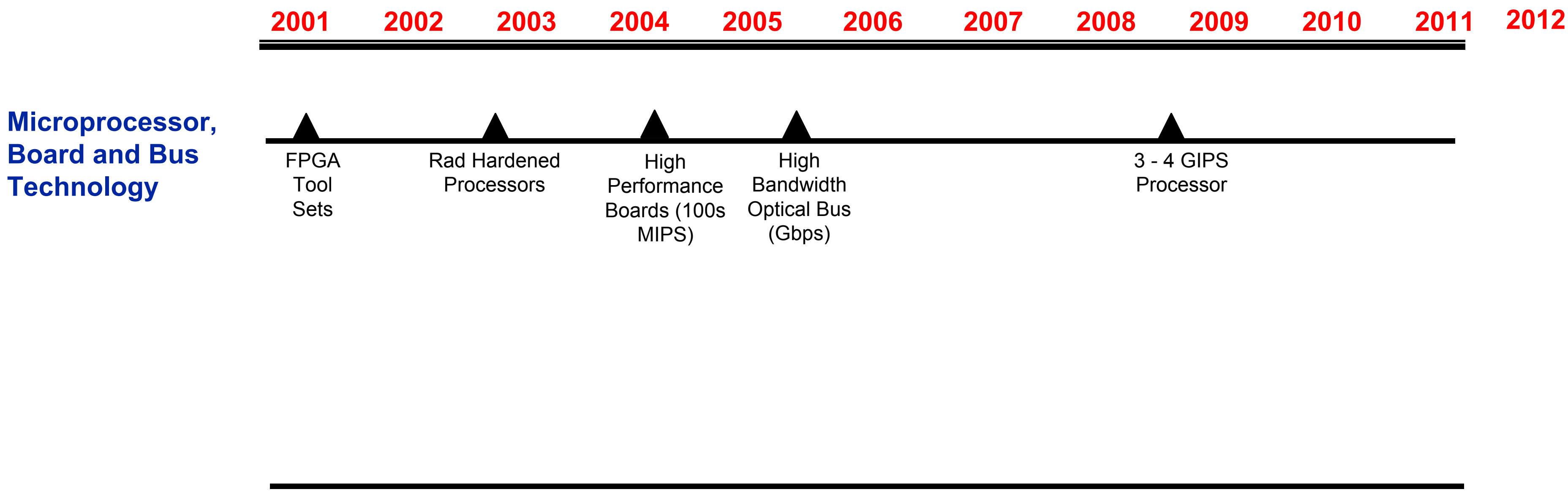


Key Space Investment Themes

AIST Key "Space" Investment Themes



AIST Key "Space" Investment Themes



AIST Key "Space" Investment Themes

2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012

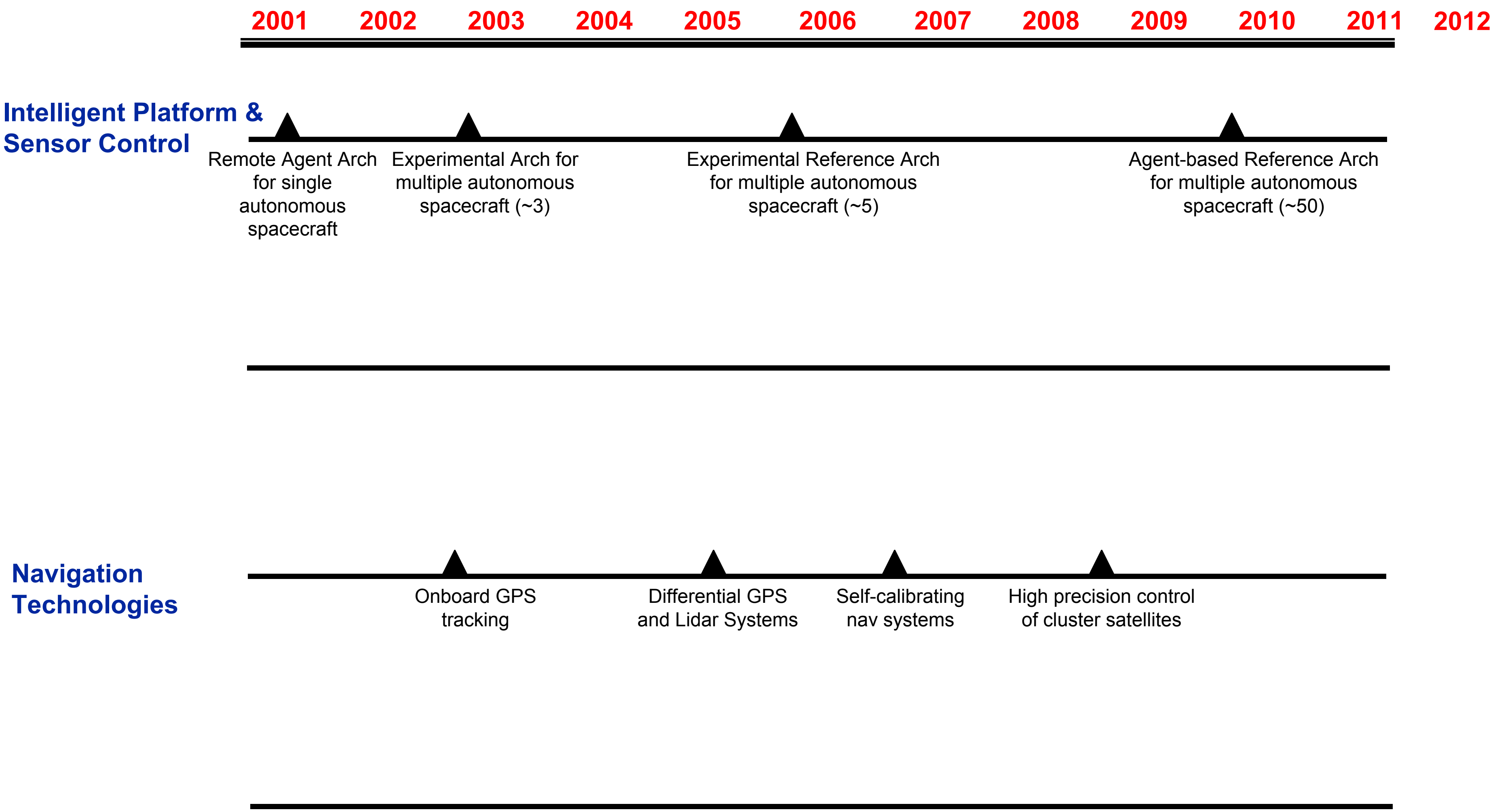
Lossless & Lossy Data Compression

- 20 Msps ~ 2:1 Comp Ratio
- JPEG Lossy Comp
- 80 Msps 2:1 Comp Ratio
- ROI Lossy Comp
- 80 Msps 3:1 Comp Ratio
- High Performance Feature Identification for Preferential Compression
- 220 Msps 5:1 Comp Ratio

Onboard Storage Architecture

- Solid State
- Magnetic/Optical Hybrid Planar 0.002 bits/μm^3 300 Mbits/sec
- Volumetric/Optical 1st Generation 0.05 bits/μm^3 500 Mbits/sec
- Volumetric/Optical 2nd Generation 0.1 bits/μm^3 1 Gbits/sec
- Volumetric/Optical 3rd Generation 0.2 bits/μm^3 2 Gbits/sec

AIST Key "Space" Investment Themes



January 9, 2002

AIST Key Investment Descriptions

The following pages describe the AIST key investment technologies that are provided in the projections worksheets.

AIST Ground Investment Themes

Earth Science Data & Services Representation

The Internet has revolutionized the distribution and representation of information. The researchers are usually overwhelmed by the available data and services. Proper representation of the Earth science data and services can save researchers and scientists valuable time and resources.

- **Research Code for Limited Semantic Extraction** – Extract semantic information from dataset to describe the contents of a file in machine-readable terms such that an application can interpret the data in an intelligent manner.
- **OGC Participation** – The Open GIS Consortium, Inc. (OGC) is a not-for-profit membership organization founded in 1994 to address the lack of interoperability among systems that process georeferenced data, and between these systems and mainstream computing systems. NASA is one of OGC's principal members. OGC's mission is to give the world's information systems a new connection to physical reality by making georeferenced data behave like just another standard data type in systems of all kinds.
- **Basic Earth Science Information Representation** - Methods of preservation of knowledge representation results; Participation in research of semantic mapping representations of data
- **"Living" Data Lineage Technique** - A living, automated record of the data, processing environments, and algorithms used to create an information product out of a data source. The data product history contains all the information necessary to recreate a product from the raw data.
- **Effective Knowledge Representation** - The association of valuable content descriptions and knowledge representation with sets of data to facilitate finding data that was previously unknown to the user of the system. Includes data exploitation tools for search fusion and mining

Earth Science Interoperable Data & Services Framework

For scientists working on multidisciplinary Earth System Science research, more than 50% of their time is spent on locating and acquiring data and information, and then preprocessing and assembling them into analysis-ready form. These time and efforts can be saved by incorporating an interoperable data and services framework.

- **Independent Tool Sets** – Independent tools for case-based reasoning, data visualization, fuzzy query and analysis, discovery of relationships between data, neutral networks exist in industry but not specific to Earth science data; each tool operates under specific environment and on specific data sets.
- **Component-based Framework with Pilot Tool Sets** – Pilot tools set to demonstrate data and services interoperability through definition, adoptions, and use of common software interfaces by communities of Earth science data researchers and application developers allowing their data products, algorithms and service code to interoperate in common frameworks
- **Component-based Framework with Comprehensive Open Tool Sets** - Open tool sets that can plug-and-play in the component-based framework to render science data services.

Knowledge Extraction

With limited time and resources available to researchers and scientists, an automated knowledge extraction scheme can be deployed to obtain valuable information that was not instinctively identifiable by manual analysis.

- **Research Code for Limited Knowledge Extraction / Change Detection** - Enable transformation of data from one or more sources into knowledge
    - Data Visualization
    - Human interactive computer "learning"
    - Feature extraction
    - Data Mining/Adaptive mining
    - Pattern recognition and statistical observation
    - Data Fusion
    - Semantic Mapping
    - Knowledge Customization/User Profiling
- **Pilot Extraction Tool Set** - Test environment and prototypes to evaluate and populate data exploitation framework
    - Pilot for specific Earth science problem(s)
    - Adapt relevant subset or tools
    - Extension into data and tool repository for scientists
- **Automatic Change Detection & Task Initiation for Sensor Webs** - Use of knowledge features, regions, models, objects, and semantics to detect changes in environment; then automatically task sensor webs to monitor regions of interest.

Information Access and Delivery

The massive and improved remote sensing data acquired by recently deployed satellites could be rendered useless if the users don't have easy access to them. Various channels will be attempted to widen the accessibility and quicker delivery of these data.

- **Independent Subscriptions/OGC-WMT participation** – Users can independently subscribe to data products; Limited user-profiling available; OGC Web Mapping Testbed being constructed and tested.
- **Partner on URN Technology** - To define both a Uniform Resource Name (URN) framework and an initial set of components that fit this framework
- **Real-time Event Recognition & Products on Demand** - Push/Pull data and knowledge delivery when an event is recognized. A service framework that contains high-speed network development, data search exploitation tools and object identification and retrieval, thus enables products on demand
- **Adaptive/Customized Subscription/Advertising Services** – User profiles/ subscription for data/knowledge push; Invest in Earth Science data exploitation infrastructure (flexible, reusable)
    - Combine data products and services
    - Tools for finding and obtaining data
    - Deal with multiple formats
    - Suite of APIs
    - Application (server) and data clearinghouse
    - Pilot set of reusable components
    - Provide web sites with mining systems, tools and services for science community

High-Performance Evolvable Archives

With the multi- and hyper-spectral data streaming in daily, the storage and archive of Earth science data have become a new challenge. Tera- and Peta-byte storage media have become a necessity not only in the Earth science regime, but the entire digital world.

- **Proprietary FSMS** – Current File Storage Management Systems are mostly company proprietary products such as UniTree, AMASS, and FileServ.
- **ANSI MS66 Metadata Interoperability Standard** - There have been some efforts to adapt a standard tape format to include File Level Metadata in a tape format. This has evolved into the work of File-Level Metadata for Portability of Sequential Storage (FMP) Study Group, which has culminated in the Association for Information and Image Management International ANSI/AIIM MS66 Proposed standard, Metadata for Interchange of Files on Sequential Storage Media Between File Storage Management Systems (FSMS)
- **Swath DBMS** – Develop a DBMS that accommodates Swath geolocation data
- **Advanced Media Benchmarks** - Media/Drive Technologies (e.g. holographic, drive interface for processing (chip)) – rely on commercialization
- **High-Performance Evolvable FSMS** - Evolvable storage media and formats including storage, archival, and retrieval standards

Data Product Planning & Scheduling

As the computers getting more powerful, the high performance data processing is also becoming a necessity. Proper management of the available computing power is essential to the success of the Earth Science Enterprise.

- **Stand-Alone Tools** – There is no unified scheduling architecture for current status of data product planning & scheduling; There are mixture of custom-coded and COTS solutions available
- **Dynamic Representation of Resource Capabilities** (archives, processors, networks) – Dynamically updates all resource capabilities so that advanced and optimized planning/scheduling can be achieved.
- **Unified Scheduling Architecture** - Performance metrics include: number of data sets and dependencies, number of ESIP members required for processing, data volume to schedule, time to accomplish task and accuracy in planning estimate, dynamic resources and replanning during task
- **Resource Manager** Learns and Improves on Performance Estimates (predict & manage) – Intelligence added to the system: learns and improves on estimates (empirical and modeled)

AIST Space Investment Themes

High Data Rate Communications

High Data Rate Communications is essential for transferring large quantities of scientific data from satellite to ground. Regardless of how the data is pre-processed or the level of on-board processing used, there will always be an increasing demand for larger communications capacities.

- **X-Band Technologies** – Current EOS systems employ X-band radio frequency technology, operating in the 7.25 – 8.4 GHz frequency band. X-band systems have been the mainstay of NASA high data rate communications, but has limited available bandwidth to serve the increasing demand for throughput over the next decade.
- **Ka-Band Technologies** – Future systems will need the wider available bandwidths provided in the 17.3 – 31 GHz frequency band. Because of the much smaller size constraint of Ka-band hardware, this technology may also be suitable for use in satellite to satellite communication applications, which could provide support for networked satellite constellations.
- **Optical Technologies** – Optical communications represents a breakthrough in terms of available bandwidth. Increases in data rate could be several orders of magnitude over RF technology. Satellite to satellite communications will almost certainly require this technology. Satellite to ground systems that use optical communications will not suffer the spectrum conflict problems associated with radio frequency transmission.

Satellite IP Network

Satellite Internet Protocol Networks will be an essential part of the sensor web concept. Sensor webs, or groups for formation flying spacecraft will need to have intra-constellation connectivity in order to hand off processing tasks, route data and enable navigation.

- **TCP over Satellite** – The Transmission Control Protocol can be demonstrated with simple end-to-end connectivity to demonstrate that the satellite platform can successfully be integrated into a computer network.
- **Onboard Routers & Switches** – By placing network routers and switches on board satellites, common data communication hardware can used and data can be routed to multiple destinations, both on and off the satellite.
- **IP over Satellite with Larger Networks –** Integration of multiple satellites and multiple ground stations into a comprehensive functional network using the Internet Protocol.
- **IP Networks on Satellites** – On-board implementation of the Internet Protocol in order to route data within the satellite and to other satellites and ground stations.
- **TDRSS Supports Routable Nets –** Integration of TDRSS into a comprehensive network and demonstration of end to end connectivity on demand.
- **Flight Qualified End-to-End IP –** Demonstration of the Internet Protocol to implement a complete functional network for collecting, transferring and analyzing science data.
- **IP to the Instrument –** Required in order to fully realize the sensor web concept. Places instrument control and use directly in the hands of the scientist.

Microprocessor, Board and Bus Technology

These component technologies are critical elements in implementing an effective on-board processing capability. They are all related to speed, flexibility and adaptability of the data collection, processing and transmission capability of the sensor system.

- **FPGA Tool Sets** – FPGAs require complex software design tools in order to make most efficient use of these devices. FPGA tools will significantly reduce the design cycle and make system testing much more effective.
- **Rad Hardened Processors** – Radiation tolerant and hardened processing devices will improve central processor reliability in the presence of radiation-induced errors. Reduction or elimination of radiation-induced errors greatly speeds data processing functions and facilitates high speed data transfer.
- **High Performance Boards (100s MIPS)** – Board architectures that can support high speed transfer of data while enduring extremes of temperature and mechanical stress are needed to host electronic processing devices with long term reliability.
- **High Bandwidth Optical Bus (Gbps)** – Bus speeds are one of the notable bottlenecks in processing. Optical bus technology will provide a revolutionary increase in the rate at which data can be moved between processors, memory and peripherals.
- **3-4 GIPS Processor** – Faster processors are essential to future Earth observing satellites. Processors that can execute 1 billion instructions per second will allow essential on-board processing functions needed in order to support data manipulation requirements of the sensor-web.

Lossless & Lossy Data Compression

Data compression allows more efficient use of available transmission bandwidth. When combined with feature identification, can significantly increase the quantity of useful scientific data collected in a time interval. The primary issues are lossless data compression and lossy data compression. Lossless data compression has mathematical boundaries on compression ratio. Lossy data compression is highly dependent upon the source and upon perception of the user.

- **20 MSPS ~2:1 Comp Ratio** – Primary issue is the capability to sample and process data at a 20 MSPS rate using current lossless compression algorithms. Primary a hardware issue coupled to on-board processing technology.
- **JPEG Lossy Compression** – JPEG standard for lossy compression will yield improved compression rates as new mathematical techniques and innovations are discovered.
- **80 MSPS/2:1 Comp Ratio** – Improved sampling and processing rate using faster hardware.
- **ROI Lossy Compression** – Region of Interest compression algorithms allow the user to select specific compression ratios on specific features or geophysical regions of a measurement or image.
- **80 MSPS/3:1 Comp Ratio** – Improved lossless compression rates due to new mathematical algorithms and techniques.
- **High Performance Feature ID for Preferential Compression** – Automated importance identification of significant features for high quality data transmission.
- **220 MSPS/5:1 Comp Ratio** – Sampling rates in the millions of samples per second require giga-ops per second processors. Lossless compression rates nearing the mathematical limits of performance capability.

Onboard Storage Architecture

Instruments having greater precision and resolution will require larger amounts of on-board storage. Data storage requirements track with data transmission rate requirements. Invariably, larger memory capacity accompanies higher data transmission capacity. New storage technologies will be essential in the implementation of the sensor web.

- **Solid State** – Current solid-state memory is low capacity and subject to radiation induced errors. However this memory is relatively inexpensive and durable over a wide range of temperature and vibration.
- **Magnetic/Optical Hybrid Planar** – Provides a memory density of 0.002 bits/mm^3 with an access rate of 300 Mbits/sec. Represents a transition technology from conventional magnetic media to fully optical.
- **Volumetric/Optical 1st Generation** – Holographic techniques will be applied to high density memory storage. First generation optical memory devices will have a memory density of 0.05 bits/mm^3 with an access rate of 500 Mbits/sec.
- **Volumetric/Optical 2nd Generation** – Second generation optical memory devices are projected to have a memory density of 0.1 bits/mm^3 with an access rate of 1 Gbits/secs.
- **Volumetric/Optical 3rd Generation** – Third generation optical memory devices are projected to have a memory density of 0.2 bits/mm^3 with an access rate of 2 Gbits/sec.

Intelligent Platform & Sensor Control

Autonomy will be an essential part of platform control. Intelligent systems will control the sensor web and integrate the platform with sensor measurement requirements. The projected intelligent platform technologies described here allow a greater number of satellites to be controlled within the sensor web.

- **Remote Agent Architecture for Single Autonomous Spacecraft** – Development and proof of capability for remote agents to assist in the control of a single satellite.
- **Experimental Architecture for Multiple Autonomous Spacecraft (~3)** – First generation capability for autonomous control of a limited number of satellites. Allows formation flying within a limited constellation. Develop concepts to extend to larger sized sensor webs.
- **Experimental Reference Architecture for Multiple Autonomous Spacecraft (~5)** – Second generation of autonomous control architectures. Incorporates new software paradigms and algorithms in order to control a greater number of satellites.
- **Agent-based Reference Architecture for Multiple Autonomous Spacecraft (~50)** – An essential capability for autonomous control of large numbers of formation flying satellites will be needed in order to fully realize the potential of the Earth Science Vision of the next 20 years.

Navigation Technologies

Precise navigation is essential for formation flying and a variety of precise geospatial measurements. New instruments will be needed that will use GPS technology in innovative ways to direct and control multiple satellite measurement systems. These instruments will help improve the accuracy and veracity of Earth science measurements.

- **On-board GPS Tracking** – Capability on-board a satellite to use fundamental GPS capability to determine and track the on-orbit location of Earth observing satellites.
- **Differential GPS and Lidar Systems** – Greatly improved accuracy is offered by differential GPS techniques. Improved geolocation accuracy will enhance the accuracy and effectiveness of Lidar systems which make measurements that require extremely precise location and pointing information.
- **Self-Calibrating Navigation Systems** – Navigation systems which are capable of making self-determined on-board calibration adjustments, and incorporating this information into the instruments performing the measurements.
- **High Precision Control of Cluster Satellites** – Highly accurate control of clusters of satellites consisting of many sensors will require the integration of precise GPS geolocation information into autonomous control systems.