Information Systems Technology Challenges for GSFC's Future Missions

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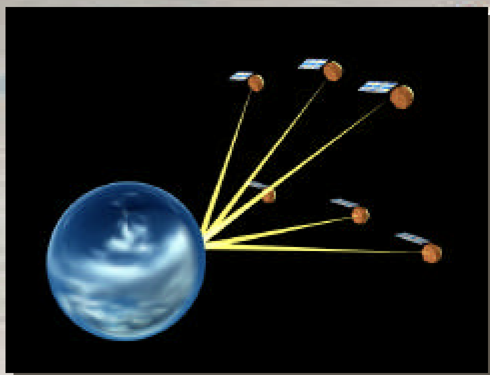
ISC Key Technology Areas - Key Drivers

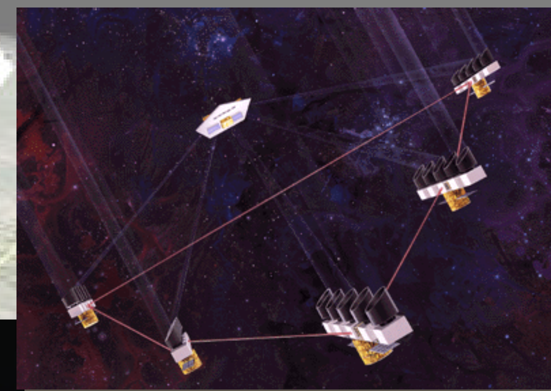
- Distributed Space Systems/Constellation
- Advanced Automation and Autonomy
- Advanced Smart Instruments
- Advanced Tools for Access and Analysis of Science Data

- Rapid Mission Formulation and Implementation
- Ultra Low-cost Mission Systems and Development

Distributed Spacecraft Systems-
Enabling New Earth & Space Science

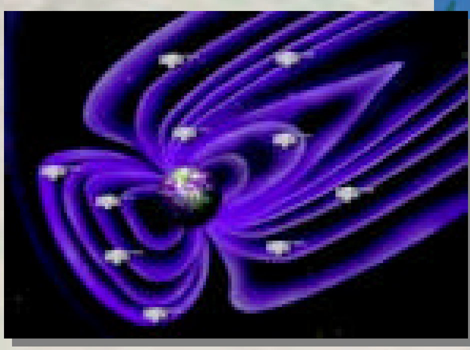


Co-observation

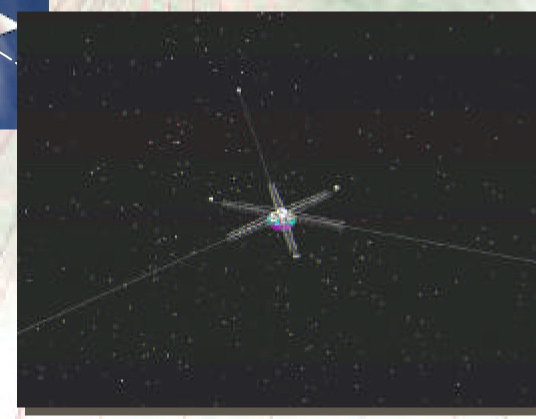


Interferometry

Coincidental Observations

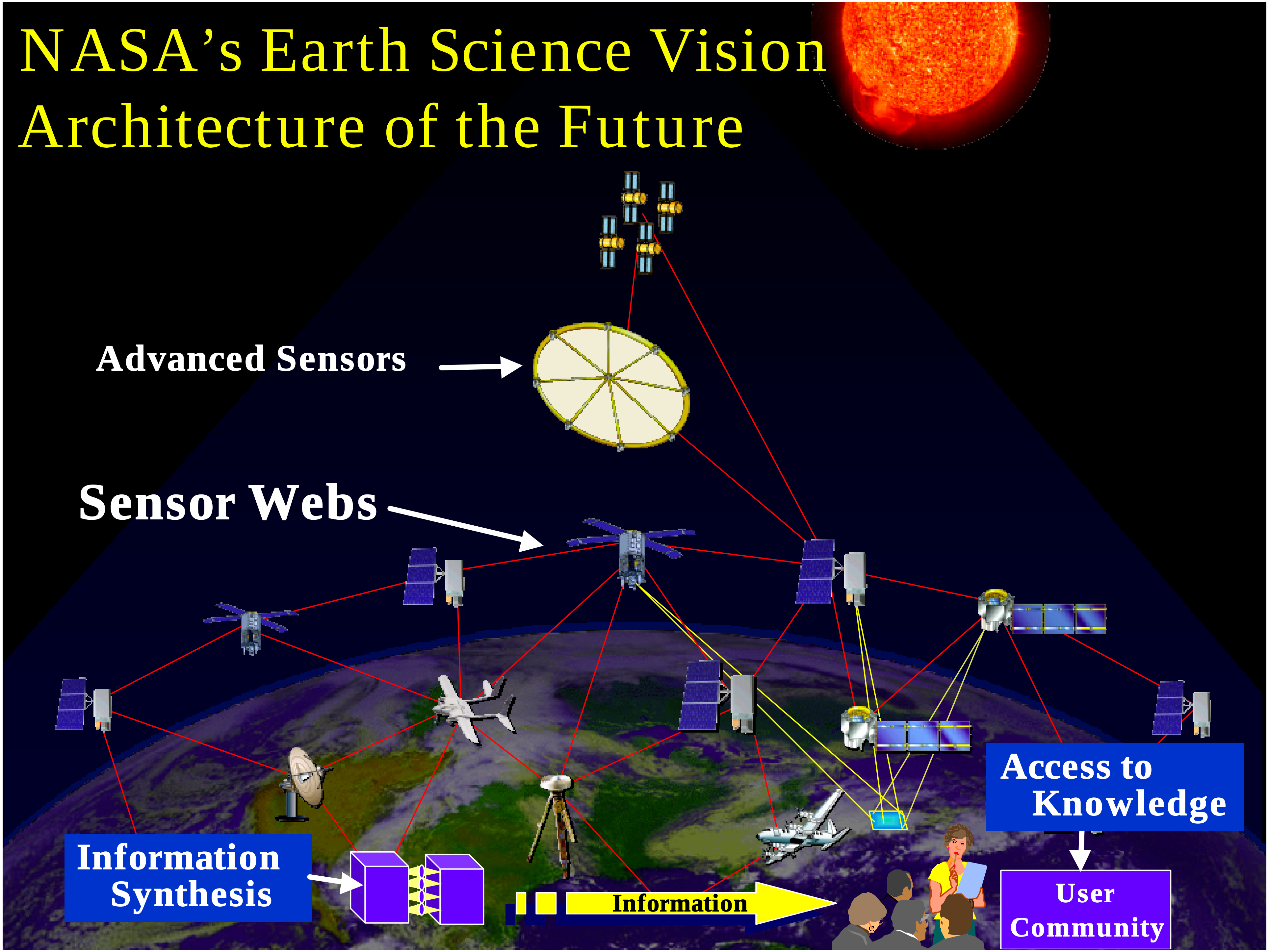


Multi-point observation



Tethered Interferometry

A new era of space exploration will be enabled by cooperating fleets of small spacecraft

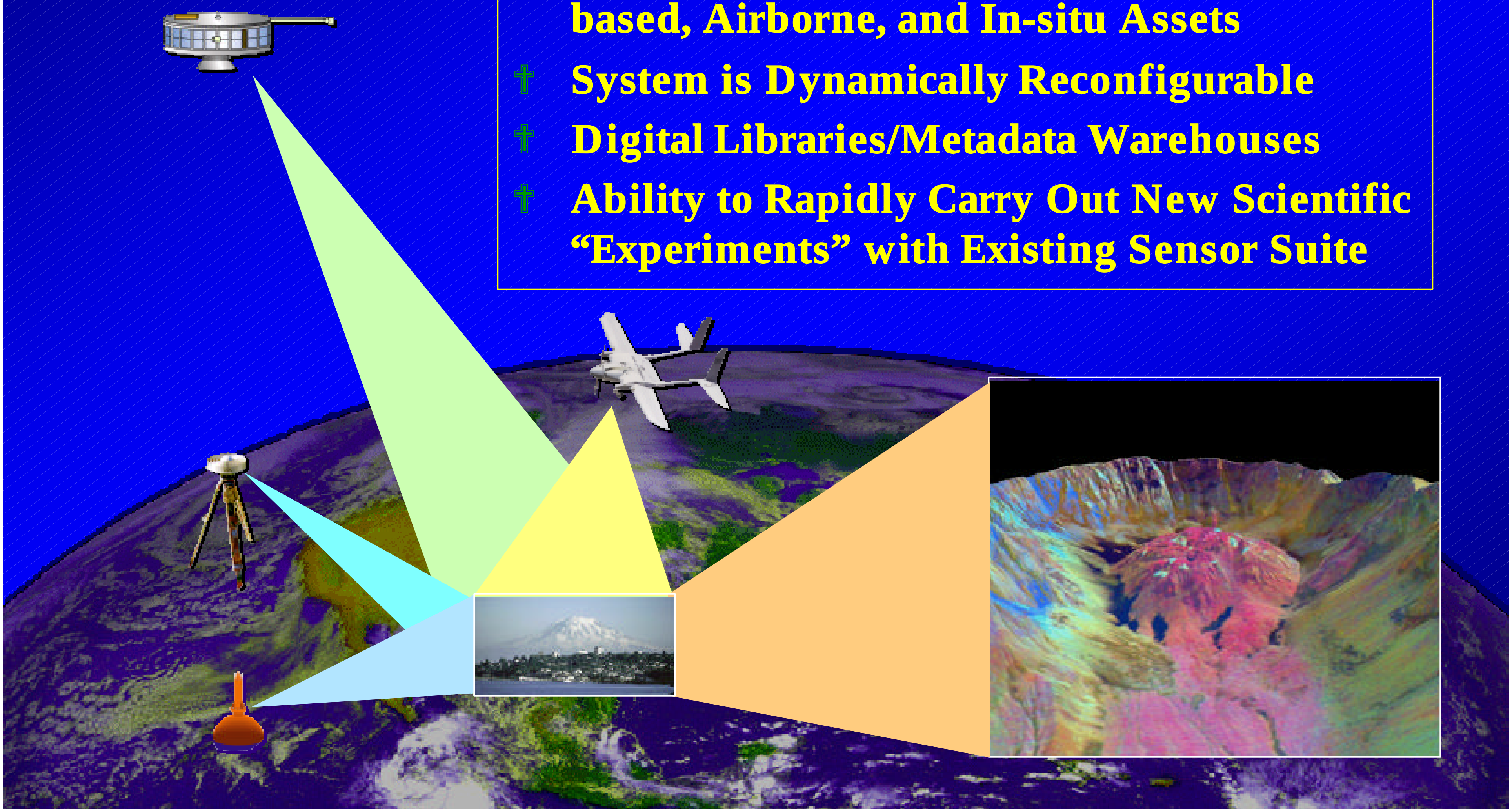

NASA's Earth Science Vision
Architecture of the Future
Advanced Sensors
Sensor Webs
Access to Knowledge
Information Synthesis
Information
User Community

NASA's Earth Science Vision-

Example: Information Synthesis in Support of Predicting & Monitoring Volcanic Eruptions

"Virtual Instruments" Derived from Space-based, Airborne, and In-situ Assets

- **System is Dynamically Reconfigurable**
- **Digital Libraries/Metadata Warehouses**
- **Ability to Rapidly Carry Out New Scientific "Experiments" with Existing Sensor Suite**



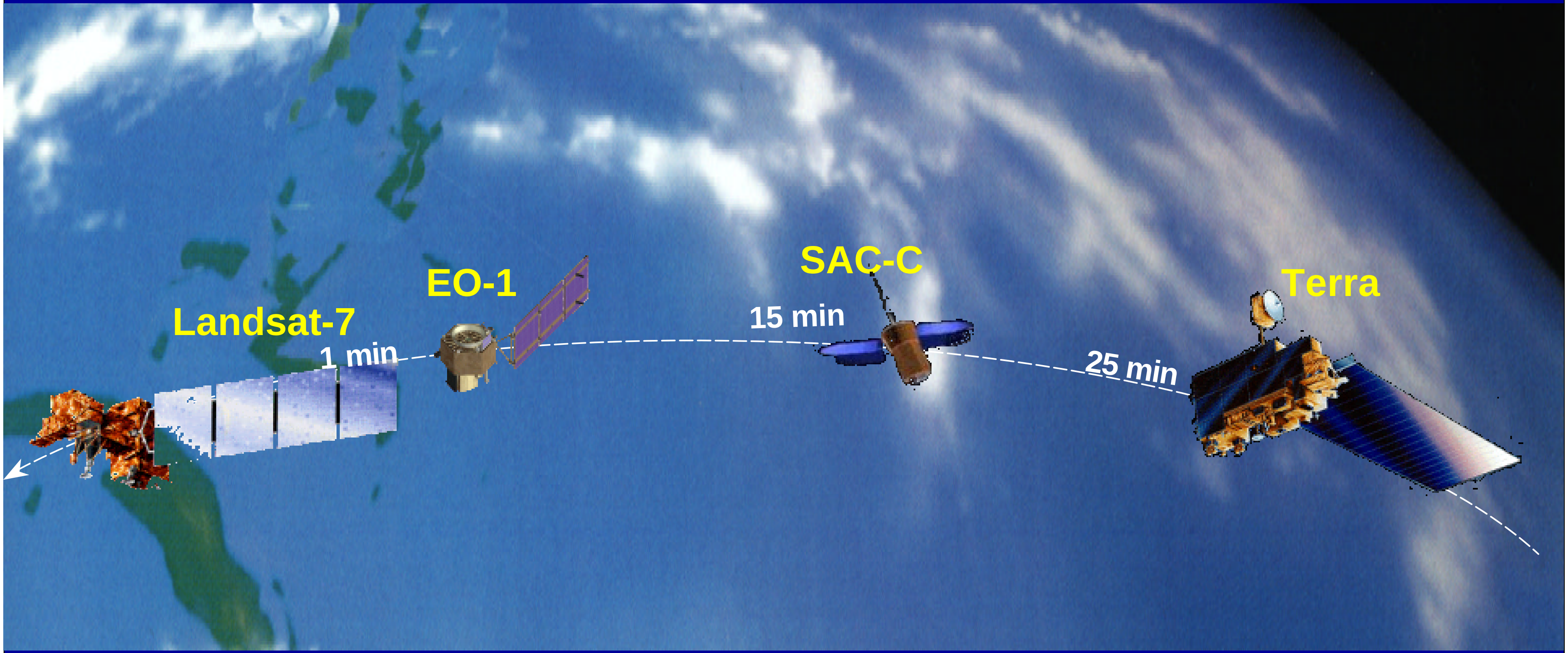
GSFC-Supported Constellation Missions*

	Mission	Technology Needs
Current (or near-term):	AM Constellation	CPS, SDF
	PM Constellation	CPS, SDF
	University Nanosat	Crosslink, AN, AGS, FC
Development (Approved):	ST-5 (NanoSat Constell. Trailblazer)	Crosslink, CPS
	TechSat-21	Crosslink, AN, FC, AMC
	MMS	Crosslink, FC
Formulation (& Pre Phase A)	MAXIM Pathfinder	Crosslink, AN, HPFC
	MAXIM	Crosslink, AN, HPFC, AMC
	GPM	AN, CPS, GDF, AGS, AMC
	MagCon (DRACO)	AN, CPS, SDF
	Radiation Belt Mappers	AN, CPS, SDF
	Solar Sentinels	AN, CPS, SDF, AMC
	Ionospheric Mappers	AN, CPS, SDF, AMC
	Constellation-X	Crosslink, AN, HPFC, AMC
	LISA Pathfinder	Crosslink (Optical), AN, HPFC
	LISA	Crosslink (Optical), AN, HPFC
Concept Development:	SPECS	Crosslink (if not tethered), AN, AMC
	MagCat	SDF, AGS, FC
	Leonardo	Crosslink, AN, SDF, FC
	Coach	Crosslink, AN
	Stellar Imager	Crosslink, AN, HPFC

Key:
CPS = Constellation Planning & Scheduling
SDF = Science Data Fusion
AN = Autonomous Navigation
AGS = Autonomous Ground Systems
FC = Formation Control
HPFC = High Precision Formation Control
AMC = Autonomous Maneuver Control

****List not exhaustive nor guaranteed to be up-to-date***

EOS “Morning” Constellation



EO-1 Objectives:

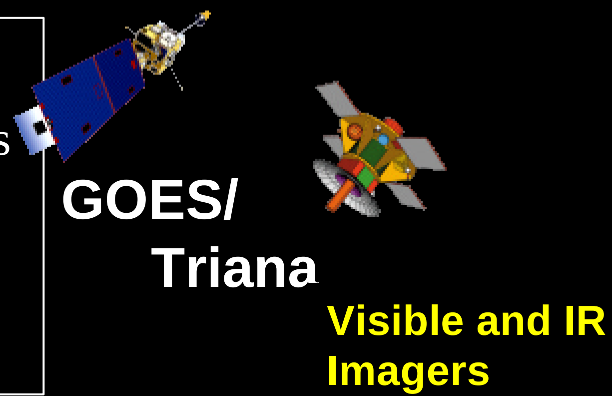
- **Perform land surface imaging in multiple bands and resolutions**
- **Validate the hyperspectral imager on EO-1**

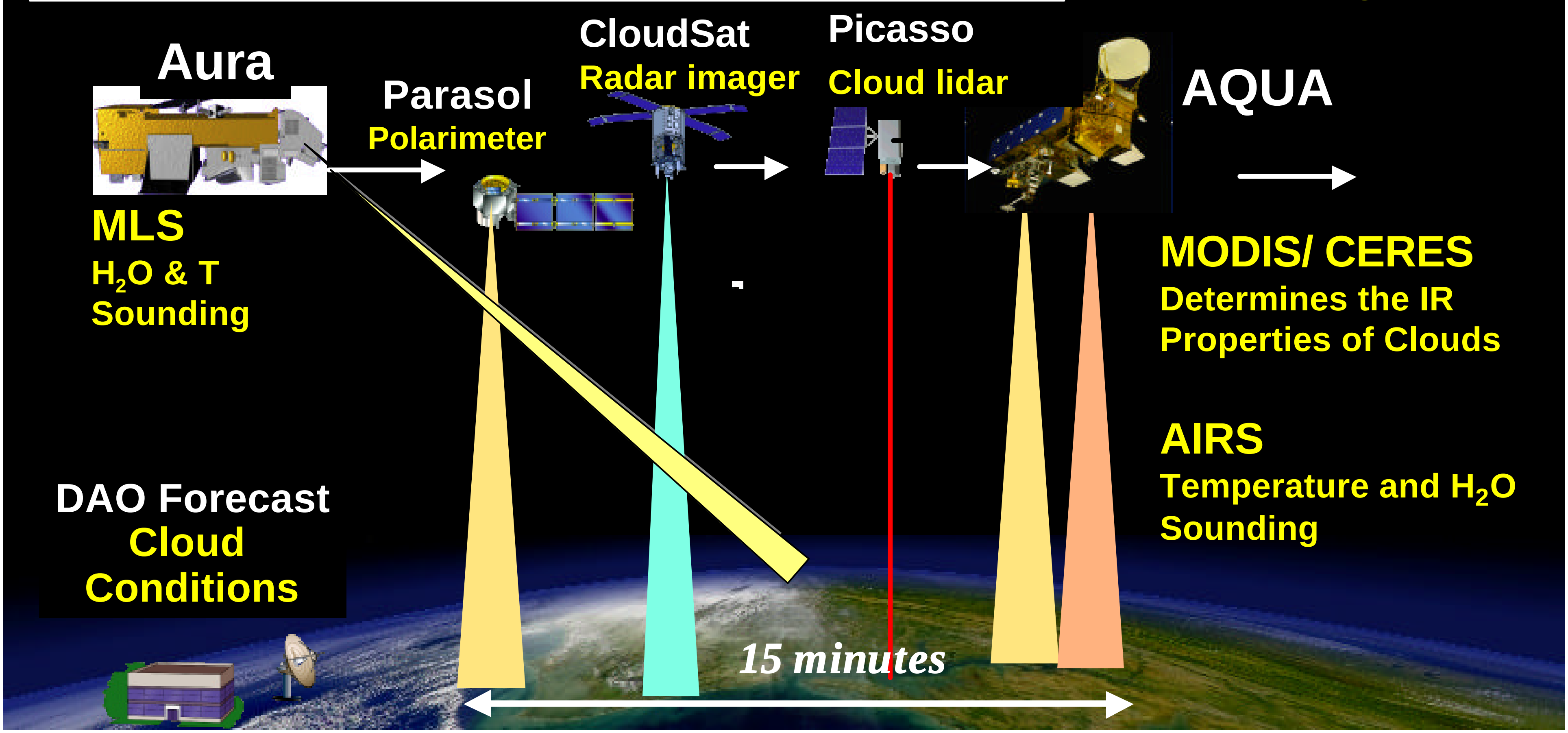
EOS "Afternoon" Constellation

***Science Goal*: Understand Cloud Properties**

Within 15 minutes, 7 satellites will view the same cloud fields

- **Multiple temperature and water vapor measurements**
- **Multiple cloud property measurements**
- **Chemical measurements**
- **Radiation measurements (IR emission, Visible reflectivity)**





NANOSAT CONSTELLATION TRAILBLAZER
NEXT CENTURY TECHNOLOGY

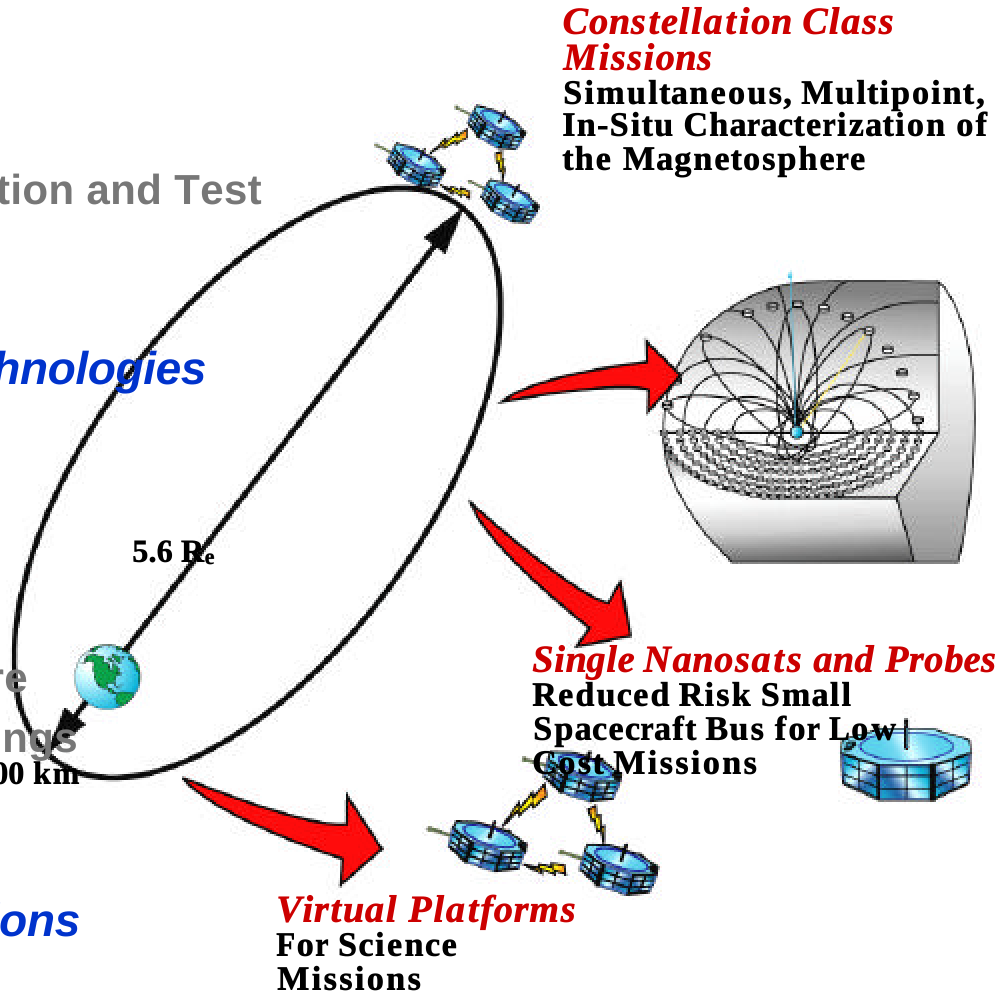
NMP ST5 Project Concept

Miniature Spacecraft

- Systems Design Integration and Test Technologies

Candidate Spacecraft Technologies

- 5V bus - 1/4V logic
- Li-Ion batteries
- Miniature transponder
- Miniature Thrusters
- Multi-functional structure
- Variable emittance coatings



Constellation Control, Coordination, and Operations Architecture

- Ground system autonomy
- Relative ranging
- Intra-constellation communications

Global Precipitation Measurement (GPM)

Mission Objective:

- Measure Rainfall Microphysics and Global Quantities on 3 Hour Time Scale

Primary Instruments:

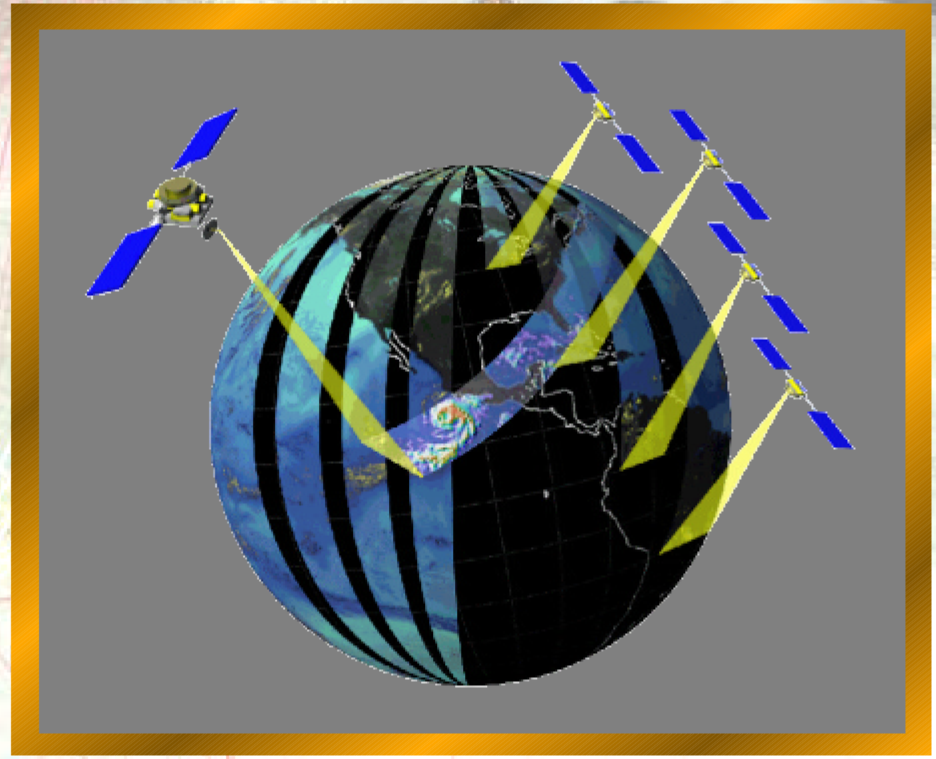
- Dual Frequency Precipitation Radar; Passive Microwave Radiometers

Key Technologies:

- Lightweight/Low-cost Rainfall Passive Microwave Radiometers
- Low Cost, Long Life Mini-Satellites

Key IS& T Technologies:

- Science Data Fusion
- Constellation Managment



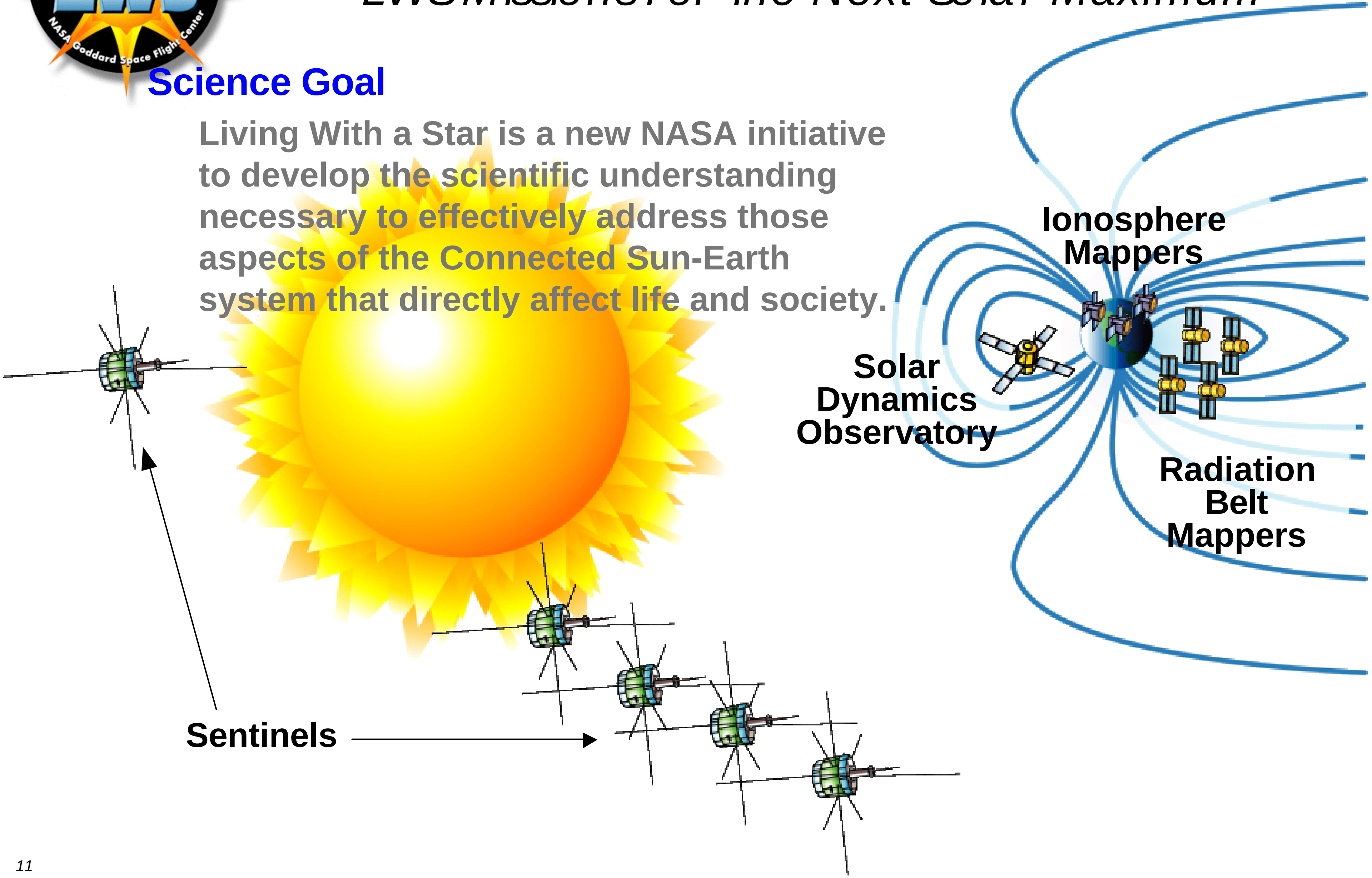
Status: The GPM Project is currently in “science definition” and “technology definition” phase as a precursor to authorization for official formulation

“Living With a Star” Missions

LWS Missions For The Next Solar Maximum

Science Goal

Living With a Star is a new NASA initiative to develop the scientific understanding necessary to effectively address those aspects of the Connected Sun-Earth system that directly affect life and society.



Technology Capabilities Needed in 2010+ Timeframe to Support Future Science Enterprise Missions

- **Multiple spacecraft, multi-instrument, multi-point observations & measurements supporting continuous dynamic studies**
  - **Constellation management**
  - **Goal-driven mission control**
  - **Automated health and status monitoring**
  - **Triage management-** ***situation assessment and information synthesis tools to help anomaly diagnosis in "lights out" situations where operators must intervene.***
  - **Intelligent user interfaces-** ***data visualization techniques to reduce information overload and present the results in an easily assimilated manner*****.**
- **Dynamic response to science event detection or changing science priorities**
  - **Event-responsive control systems**
  - **Dynamic planning/replanning**
  - **Goal-driven mission control**
  - **Spacecraft-initiated communications events/ situation alerts**
- **Information shared seamlessly between sensors & sciencecraft**
  - **Common communication schemes**
  - **Collaborative payload and platform tasking ….**

Mission Autonomy Technologies

Guidance Navigation & Control
? Onboard trajectory determination
? Trajectory planning
? Maneuver design & execution
? Feature identification and tracking
? Target relative maneuvering
? Hazard collision avoidance
Multiple S/C
? Formation keeping
? Coordinated Platforms
✍ Resource sharing
✍ Science data gathering
q Information fusion
? Engineering sensor data fusion
Science observation
? Science data fusion
? Re-targeting to repeat science observations
? Capture opportunistic science
? Optimize science downlink data

Goal-based commanding
? Task decomposition
? Automated sequencing
? Event driven sequencing
Onboard planning
? Automated planning
? Planning in uncertain environments
? Dynamic planning & plan optimization
? Contingency planning
? Real time scheduling
S/C resources
? Resource management and optimization
? Self monitoring and selective health reporting
Anomaly resolution
? Model-based fault protection
? Flexible contingent response
? Response to unanticipated faults

ISC Strategic Technology Focus Areas
Objectives and Visions

The ISC Strategic Plan is currently based on 3 major technology focus areas:

1. Rapid Mission Formulation, Design & Execution:
Enabling revolutionary mission concepts through rapid mission formulation, implementation and execution
Vision: Mission scientists and engineers seamlessly evolve science objectives into mission concepts through virtual model to an operational science system

2. End-to-End System Autonomy:
Enabling effortless science collection through autonomous mission systems

Vision: Mission scientists operate, maintain and reconfigure systems from anywhere in order to optimize an on-board observation and maximize science return

3. Advanced Scientific Analysis Tools & Data Systems:
Enabling science knowledge discovery through seamless and transparent access to information
Vision: Academic and research community has continuous and transparent access to data and information for scientific research

ISC Strategic Technology Capability Roadmap*

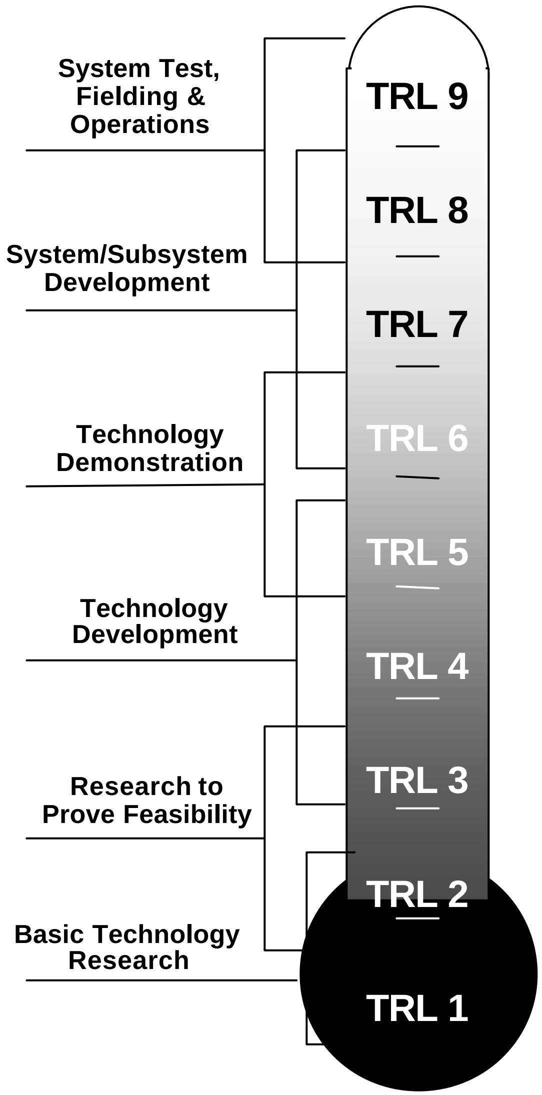
(Key Capabilities for future Mission Information Systems)

ISC Technology Focus Areas	*Near (2003)*	*Mid (2006)*	*Far (2010)*
Rapid Mission Formulation, Design, and Execution	•Low Cost, Internet-based, Secure Distributed Computing Architectures. •Data interface and distribution framework for Subsystem Design and Analysis Tools •System-level, Model-based design	•Collaborative Design & Operations Environments. •Integrated Simulation and Design Systems	•Immersive Virtual Environments for Collaborative Engineering and Science
End-to-End System Autonomy	•Ground-based, Goal Driven Commanding •Science Feature Identification •Automated Spacecraft Health & Safety •Missions operate as IP nodes on the net	•On-board, Goal Driven Commanding drives Reactive Mission Execution •Constellation Management •Mission operates as mobile-IP nodes on the net	•Multi-mission collaboration for Dynamic Science Agenda •Mission operate as mobile-routering nodes on the net
Advanced Scientific Analysis Tools & Data Systems	•User selectable subscription services for Data Distribution •Feature Extraction and Identification Tools (Data Mining & Knowledge Capture) •Platform Independent Visualization & Analysis Tools •Real-time Updates to Science Models •Interface and Distribution Framework for Science Data & Science Models	•Multi-S/C (including Constellations) Data Processing, Fusion & Analysis •Advanced Information Prospecting and Capture Tools •Collaborative Visualization and Analysis tools •Collaborative (Multi-Source) Updates to Science Models	•Seamless, transparent access to distributed data, info. and knowledge ("Virtual Data Communities") •Knowledge Extraction using Natural Language Interface in an Immersive Environment

* v1.2 - 9/13/99

Technology Readiness Levels

Applied to Systems (v1.0*)



TRL 9: Actual system "mission proven" through successful mission operations (ground or space) *Fully integrated with operational hardware/software systems. Actual system has been thoroughly demonstrated and tested in its operational environment. All documentation completed. Successful operational experience. Sustaining engineering support in place.*

TRL 8: Actual system completed and "mission qualified" through test and demonstration in an operational environment (ground or space) *End of system development. Fully integrated with operational hardware and software systems. Most user documentation, training documentation, and maintenance documentation completed. All functionality tested in simulated and operational scenarios. V&V completed.*

TRL 7: System prototype demonstration in operational environment (ground or space) *System prototype demonstration operative. System is at or near scale of the operational system, with most functions available for demonstration and test. Well integrated with collateral and ancillary systems. Limited documentation available.*

TRL 6: System/subsystem model or prototype demonstration in a relevant end-to-end environment *Prototype implementations on full-scale realistic problems. Partially integrated with other systems. Limited documentation available. Engineering feasibility demonstrated in actual system application.*

TRL 5: System/subsystem/component validation in relevant environment *Thorough testing of prototype in representative environment. Basic technology elements integrated with reasonably realistic supporting elements. Prototype implementations conform to target environment and interfaces.*

TRL 4: Component/subsystem validation in laboratory environment *Standalone prototype implementation and test. Integration of technology elements. Experiments with full-scale problems or data sets.*

TRL 3: Analytical and experimental critical function and/or characteristic proof-of-concept *Proof of concept validation. Active R&D is initiated with analytical and laboratory studies. Demonstration of technical feasibility using breadboard/brassboard implementations that are exercised with representative data.*

TRL 2: Technology concept and/or application formulated *Applied research. Theory and scientific principles are focused on specific application area to define the concept. Characteristics of the application are described. Analytical tools are developed for simulation or analysis of the application.*

TRL 1: Basic principles observed and reported *Transition from scientific research to applied research. Essential characteristics and behaviors of systems and architectures. Descriptive tools are mathematical formulations or algorithms.*

**not guaranteed to be latest version*