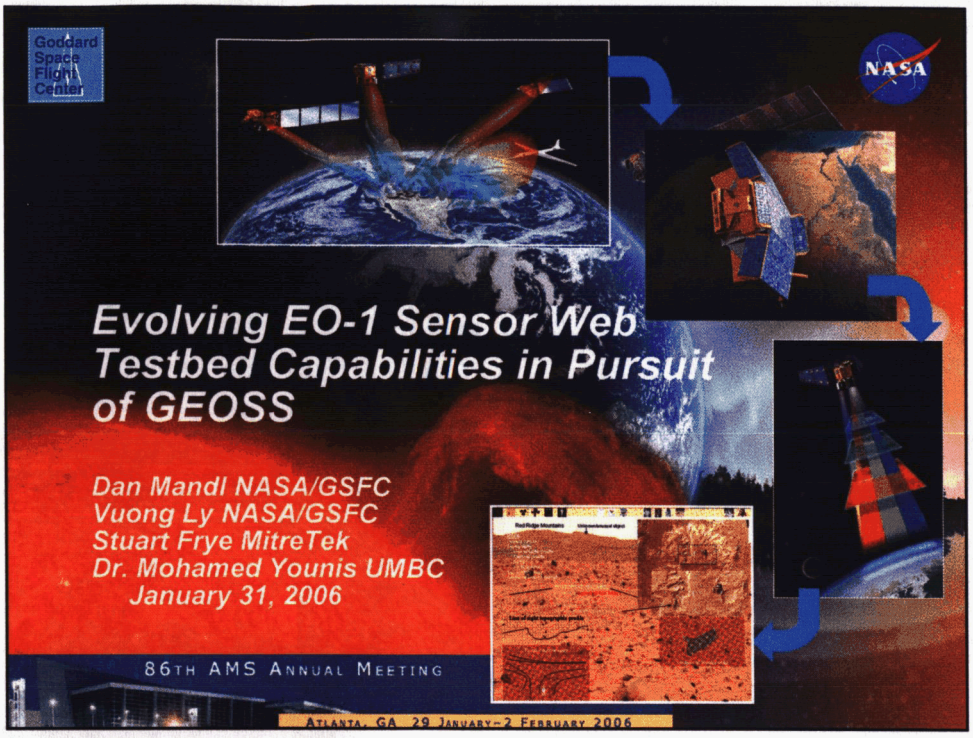
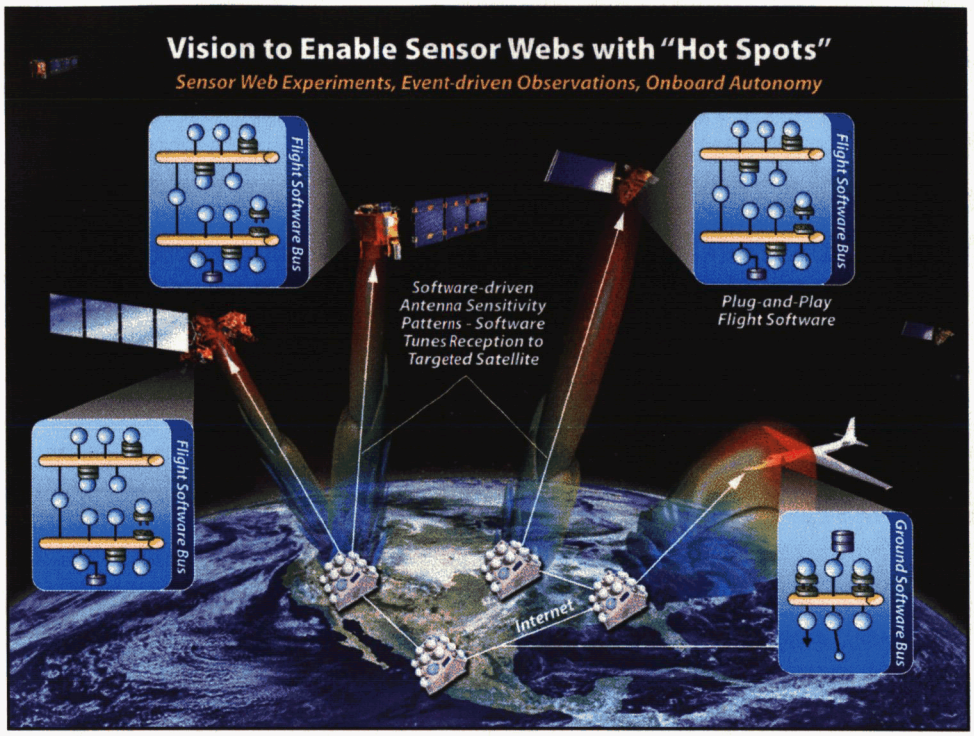
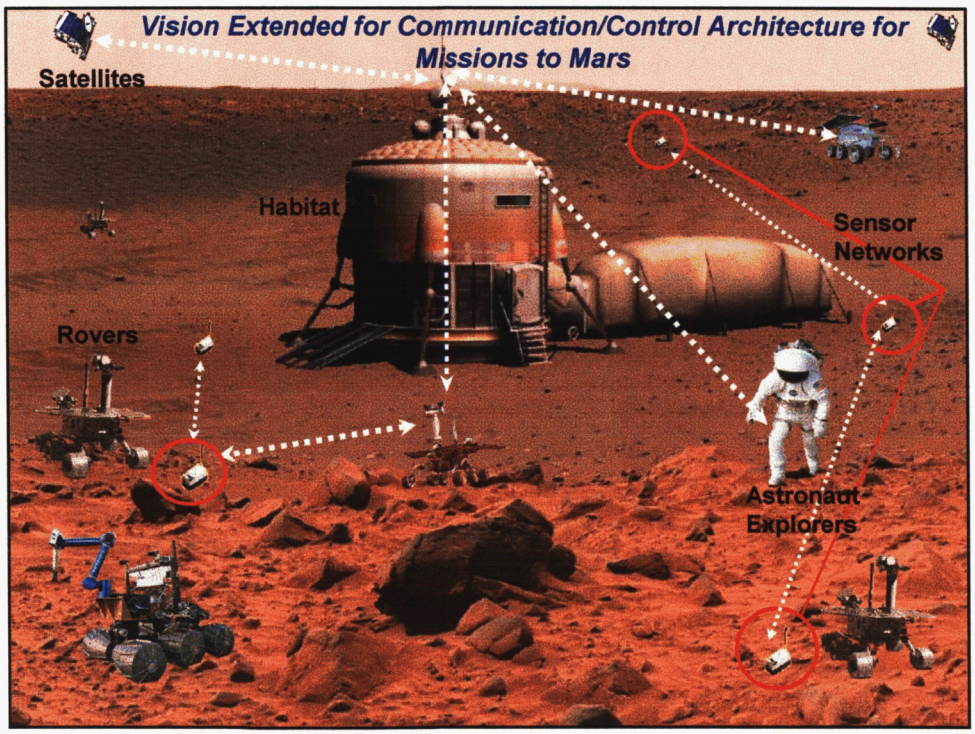


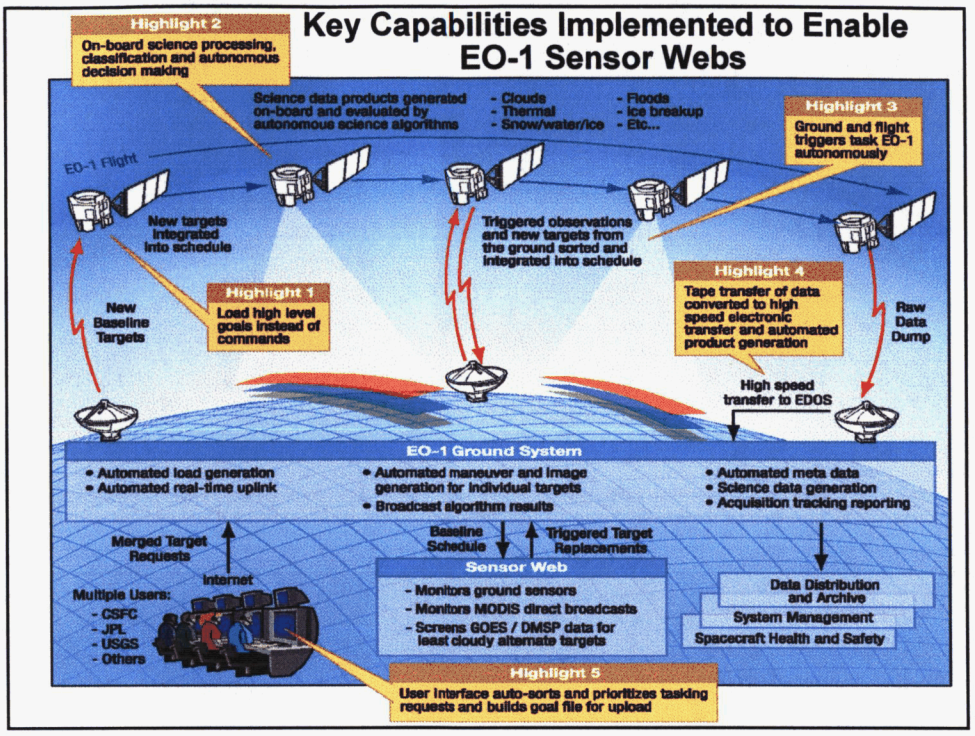
Overview

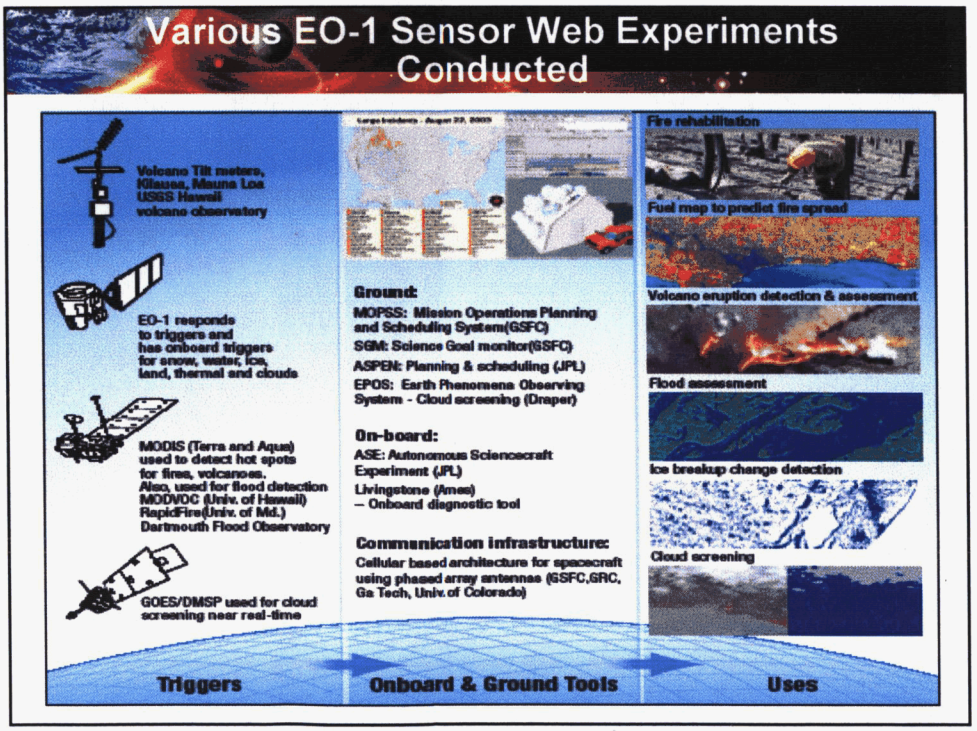
- Definition of sensor web
  - Coherent collection of sensors, space-based and/or ground based, and computation nodes linked by a communication fabric and collectively act as a single, dynamically adaptive, observing system (Talabac/GSFC)
- Sensor webs use autonomic computing and components:
  - Have self-awareness
  - Self-optimize
  - Self-heal
  - Self-protect
  - Negotiate (peer-to-peer) for resources
  - Function in a heterogeneous world and with open standards
  - Anticipate needed resources and hides details needed to obtain resources
- Evolve sensor web capabilities in pursuit of capabilities to support Global Earth Observing System of Systems (GEOSS)

2


Vision to Enable Sensor Webs with "Hot Spots"
Sensor Web Experiments, Event-driven Observations, Onboard Autonomy
Flight Software Bus
Flight Software Bus
Software-driven Antenna Sensitivity Patterns - Software Tunes Reception to Targeted Satellite
Plug-and-Play Flight Software
Flight Software Bus
Internet
Ground Software Bus


Vision Extended for Communication/Control Architecture for Missions to Mars
Satellites
Habitat
Sensor Networks
Rovers
Astronaut Explorers


Key Capabilities Implemented to Enable EO-1 Sensor Webs
Highlight 2
On-board science processing, classification and autonomous decision making
Science data products generated on-board and evaluated by autonomous science algorithms
- Clouds
- Thermal
- Snow/water/ice
- Floods
- ice breakup
- Etc...
Highlight 3
Ground and flight triggers task EO-1 autonomously
EO-1 Flight
New targets integrated into schedule
Triggered observations and new targets from the ground sorted and integrated into schedule
Highlight 1
Load high level goals instead of commands
Highlight 4
Tape transfer of data converted to high speed electronic transfer and automated product generation
New Baseline Targets
Raw Data Dump
High speed transfer to EDOS
EO-1 Ground System
• Automated load generation
• Automated real-time uplink
• Automated maneuver and image generation for individual targets
• Broadcast algorithm results
• Automated meta data
• Science data generation
• Acquisition tracking reporting
Merged Target Requests
Internet
Baseline Schedule
Triggered Target Replacements
Sensor Web
- Monitors ground sensors
- Monitors MODIS direct broadcasts
- Screens GOES / DMSP data for least cloudy alternate targets
Multiple Users:
- CSFC
- JPL
- USGS
- Others
Data Distribution and Archive
System Management
Spacecraft Health and Safety
Highlight 5
User interface auto-sorts and prioritizes tasking requests and builds goal file for upload


Various EO-1 Sensor Web Experiments Conducted
Volcano Tilt meters, Kilauea, Mauna Loa USGS Hawaii volcano observatory
EO-1 responds to triggers and has onboard triggers for snow, water, ice, land, thermal and clouds
MODIS (Terra and Aqua) used to detect hot spots for fires, volcanoes. Also, used for flood detection
MODVOC (Univ. of Hawaii)
RapidFire(Univ. of Md.)
Dartmouth Flood Observatory
GOES/DMSP used for cloud screening near real-time
Ground:
MOPSS: Mission Operations Planning and Scheduling System(GSFC)
SGM: Science Goal monitor(GSFC)
ASPEN: Planning & scheduling (JPL)
EPOS: Earth Phenomena Observing System - Cloud screening (Draper)
On-board:
ASE: Autonomous Sciencecraft Experiment (JPL)
Livingstone (Ames)
– Onboard diagnostic tool
Communication infrastructure:
Cellular based architecture for spacecraft using phased array antennas (GSFC,GRC, Ga Tech, Univ. of Colorado)
Fire rehabilitation
Fuel map to predict fire spread
Volcano eruption detection & assessment
Flood assessment
Ice breakup change detection
Cloud screening
Triggers
Onboard & Ground Tools
Uses

One of Three Experiments Conducted by UMBC Undergraduate Class 12-14-05 (1 of 3)

- Students used the following interconnected assets
  - EO-1
  - Wireless Sensor Network (set of 6 motes 1" x 2" each)
  - Personal Exploration Rover (PER) or Mini-rover
  - Laptop computer and wireless router
- Three project teams from Computer Science class conducted three experiments
- Explanation of one of the experiments (Emergency Response Network)
  - One of 6 sensor motes turned off to simulate failure
  - Mini-rover automatically finds broken mote and goes to location and takes picture
  - Message sent automatically to EO-1 to also take a picture of site which, in this case, is the whole UMBC campus

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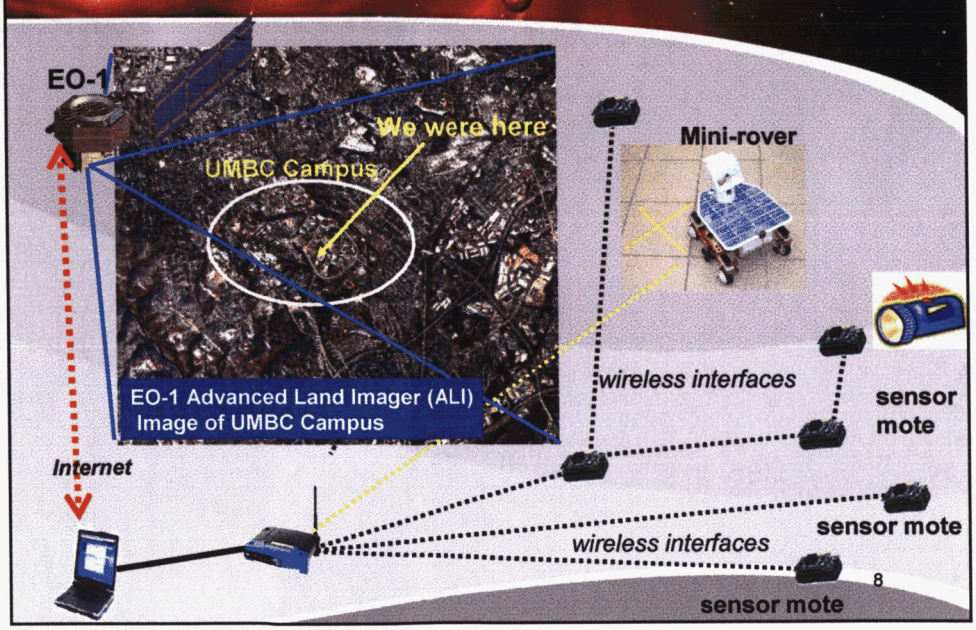
One of Three Experiments Conducted by UMBC Undergraduate Class 12-14-05 (2 of 3)



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Experiment with UMBC Undergraduate Class 12-14-05 (3 of 3)

Picture of Experiment Day

Sensor network class, Dr. Younis, Vuong Ly and Dan Mandl

Sensor mote layout & atrium where experiment conducted (inset)

Mini-rover in action

Baltimore Sun reporter

Mini-rover autonomously finding broken sensor node (part of Emergency Response UMBC project team)

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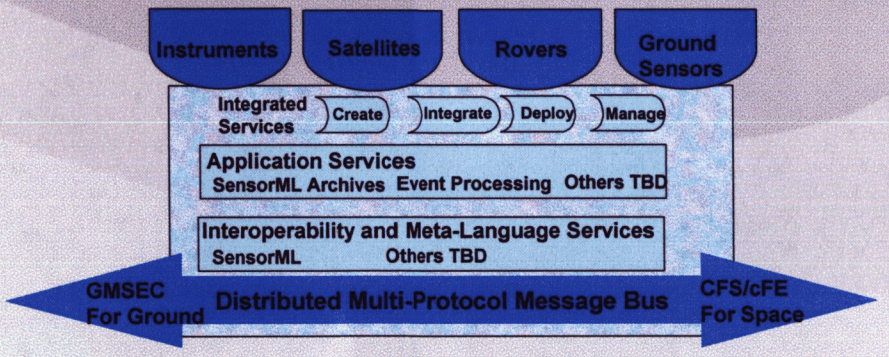
Closer Look at our Mini-Rovers & Simulated Mars Landscape at GSFC

Beginning to Implement Experiments with Standards - Vision for Integrated Sensor Web Environment

- GSFC Mission Systems Evolution Center (GMSEC)
- Core Flight Executive (cFE)
- Core Flight System (CFS)
- SensorML



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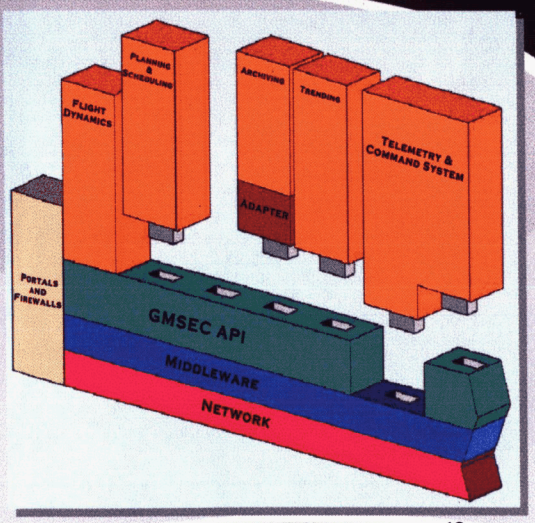
Goddard Mission Services Evolution Center (GMSEC)

GMSEC architecture provides a scalable and extensible ground and flight system approach

- Standardized messages formats
- Plug-and-play components
- Publish/Subscribe protocol
- Platform transparency
- More info at: http://gmsec.gsfc.nasa.gov



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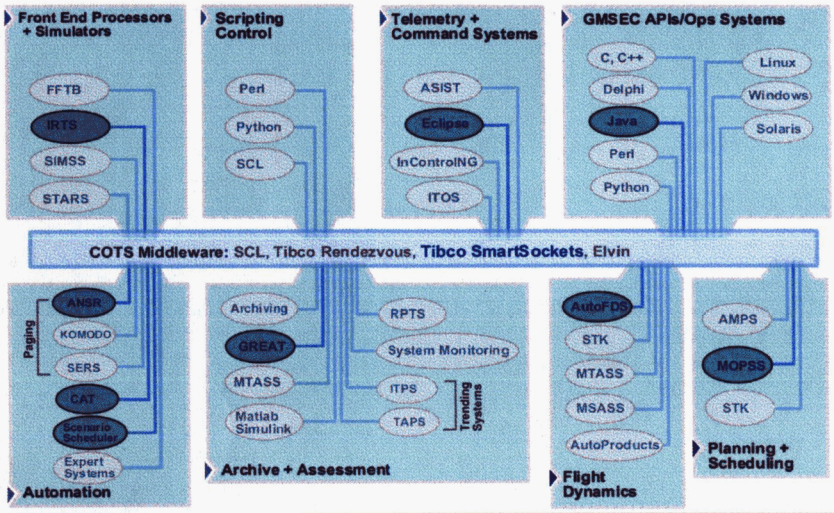
GMSEC Component Catalog

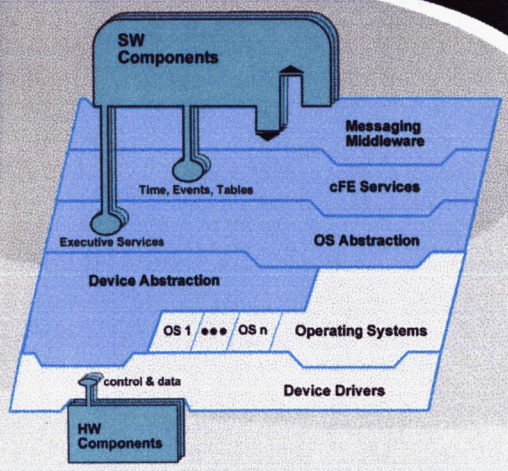
GMSEC approach gives users choices for the components in their system. The TRMM mission has selected key components from the GMSEC catalog.



Core Flight System (CFS) and Extension for GMSEC for Flight SW

CFS provides a framework that simplifies the development and integration of applications

- Layered Architecture – software of a layer can be changed without affecting the software of other layers
- Components communicate over a standard message-oriented software bus, therefore, eliminating the need to know the details of the lower layers of inter-networking.
- Software components can be developed and reused from mission to mission.
- Developed by Flight Software Branch at GSFC
- More info at: http://gmsec.gsfc.nasa.gov



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Sensor Modeling Language

- XML based
- Provides general sensor information to support data discovery
- Supports processing and analysis of sensor data
- Supports geo-locations of sensor data
- Provides performance characteristics (accuracy, thresholds, etc.)
- Archive fundamental properties and assumptions regarding sensors
- Can apply to any sensor whether in-situ or remote
- Facilitates "plug and play" and interoperability between sensors
  - Especially useful for heterogeneous sets of sensors and rapid integration of new sensors

From---- http://vast.nsstc.uah.edu/SensorML/

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Began Using Cosmic Hot Interstellar Plasma Spectrometer (CHIPS) in Fall 2005

- PowerPC
- Ground to space IP connection
- 128 Mbytes of Memory
- Perfect for Experiments
  -(E.g. Secure IP to S/C)

**** OPEN FOR BUSINESS 9/1/05 *******

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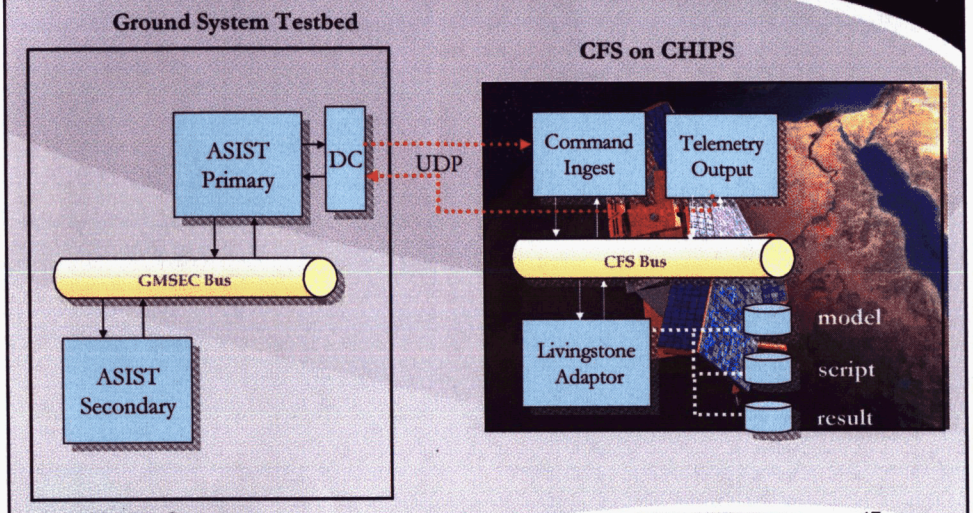
Seamless Ground to Space Integrated Message Bus Demonstration (completed December 2005)



DC – Data Center
ASIST – Advanced Spacecraft Integration and System Test

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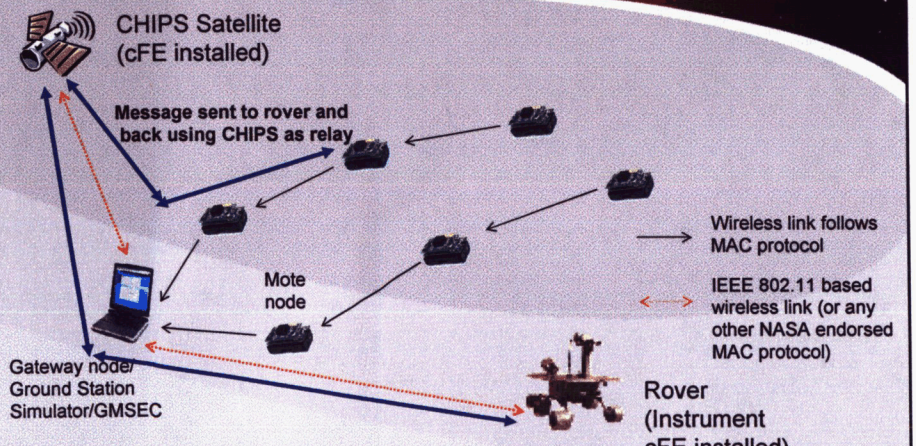
Next Steps: Target Future Demonstration Architecture

(Target December 2005 – February 2006)



- Integrate this demonstration on-orbit using CHIPS
- Use CHIPS as message relay
- Integrate Rover and instrument CFS
- Collaboration with UMBC

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Other Experiments in Queue

- Demonstrate instant porting of ground components to satellites
- Network Time Protocol
- IP Security
- Onboard file management
- Integrate SensorML into some experiments using an assortment of sensors, rovers and satellites

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Acknowledgements

- Other key participants in EO-1 sensor web work:
  - Steve Chien, Robert Sherwood, Ashley Davies, Daniel Tran, Greg Rabideau, Rebecca Castano, Nghia Tang, Michael Burl / JPL
  - Sandra Hayden, Scott Christa, Adam Sweet, Lee Brownston / QSS / AMES
  - Steve Ungar, Tom Brakke, Jeremy Jones / GSFC
  - Lawrence Ong, Sandra Hayden / SSAI/GSFC
  - Jerry Hengemihle, Nick Hengemihle, Bruce Trout / Microtel LLC/GSFC
  - Jeff D'Agostino, Kathleen Blackman/Hammers Corp/GSFC
  - Seth Shulman, Joseph Szwaczkowski, Robert Bote / Honeywell/GSFC
  - Jim VanGaasbeck, Darrell Boyer, Brian Gregory, Phil Courtney / Interface & Control Systems, Inc.
  - Michael Griffin, Hsiao-hua Burke / MIT LL
  - Robert Greeley, Thomas Dogett, Kevin Williams/ Arizona State Univ
  - Victor Baker, James Ohm / Univ. of Arizona
  - Rob Sohlberg, Chris Justice, Jessica McCarty / Univ. of Md.
  - Anarahda Koratkar / Univ. of Md at Baltimore County

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- 5. 45 papers and 41 more articles on EO-1 sensor web work at: http://eo1.gsfc.nasa.gov/new/general/resources/papers.html
- 6. Information on EO-1 in general:

  http://eo1.gsfc.nasa.gov/
- 7. Information on GMSEC and CFS:

  http://gmsec.gsfc.nasa.gov

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