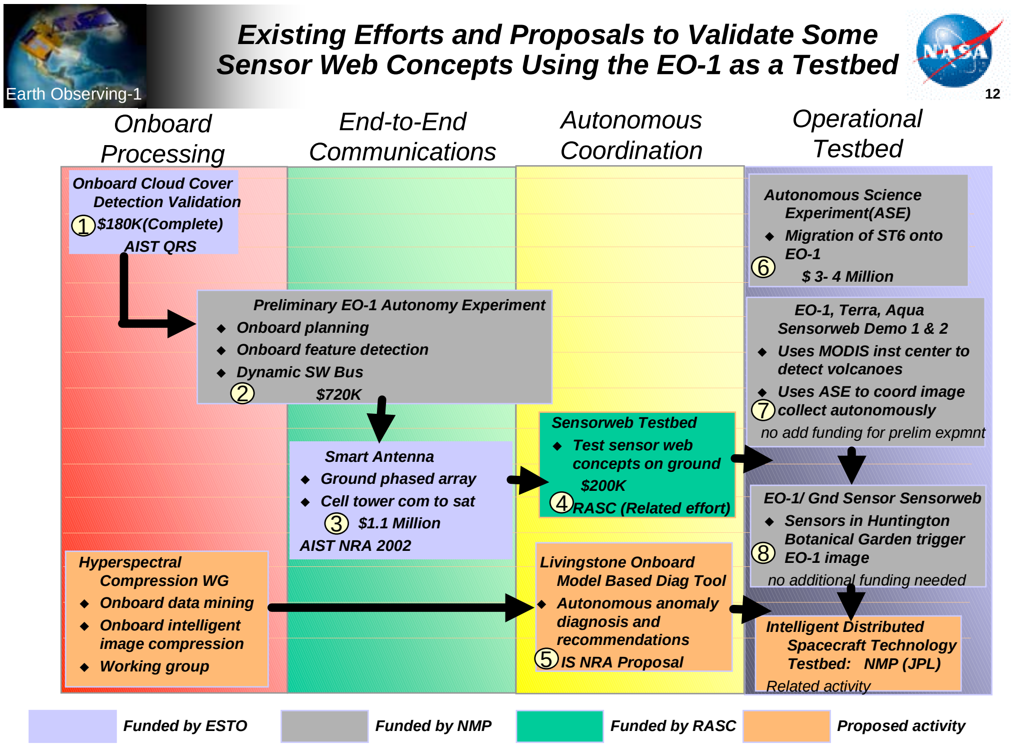
EO-1 Testbed Overview 6-8-03

The purpose of using EO-1 as a testbed is to validate some key concepts necessary to implement sensor webs in the future. The key capability is to create a mission wide, end-to-end information bus that performs like the internet. A user should be able to send a message to any software task used on the mission (whether space or ground) by naming it and the sensor web system should take care of the details. Once this end-to-end information bus is available, then progressive mission autonomy is easily created by writing scripts and using various autonomy applications on top of this messaging system. To optimize this messaging system mission-wide, the space to ground interface must be seamless and the spacecraft-to-spacecraft interface must be seamless. An important concept is that the messaging system sits on top of any protocol whether it is TCP/IP or any other protocol For example, if you make a phone call, all that you care about is that the phone call gets to the targeted party. The phone call may be routed through the internet and two other phone systems. Finally, we can use these capabilities to group a set of unrelated satellites and for some arbitrary time declare them a functional constellation such as is the case for the “Morning Constellation” with the key difference being that they act functionally uniform as is the case with many disparate functions on the internet.

For the purposes of these activities, we are calling the messaging system a “Dynamic Software Bus”. It is built on top of the existing EO-1 software bus which is a static software bus. The key added feature that we are adding is the “Dynamic” ability to plug new applications in, whether on the satellite or on the ground and have the system recognize the application by name. Applications added to this system, such as the CASPER onboard planning system, enable the larger concept of Dynamic Resource Management whereby this distributed constellation system takes care of many of the details of allocating and managing resources. In our initial demonstration, a part of the EO-1 tasking process will be handled onboard by CASPER which will plugged into the dynamic software bus that we have implemented on EO-1.

One other problem that we are trying to solve is that of limited contacts for low earth orbiting satellites. If a user wants to message a low earth orbiting satellite at present, there is a limitation of 4 –8 ea. 10 minute passes for satellites such as EO-1. This does not lend itself well to the concept of having a messaging system that can access a satellite from anywhere in the mission at any time. Therefore, we are also trying the develop a concept of inexpensive, ground phased array antennas that would be placed around the country and perhaps the world to provide as close to total coverage as possible, thus making the dynamic software bus for a mission more of a reality. This is especially essential if true progressive autonomy is desired whereby functionality is inserted into an ad hoc constellation mission while on-orbit.

The activities structured thus far in the “testbed” phase of EO-1 attempt to validate some of these concepts. Figure 1 shows the activities thus far initiated with color coding to show which activities are funded and which are proposed:



Existing Efforts and Proposals to Validate Some Sensor Web Concepts Using the EO-1 as a Testbed

Earth Observing-1
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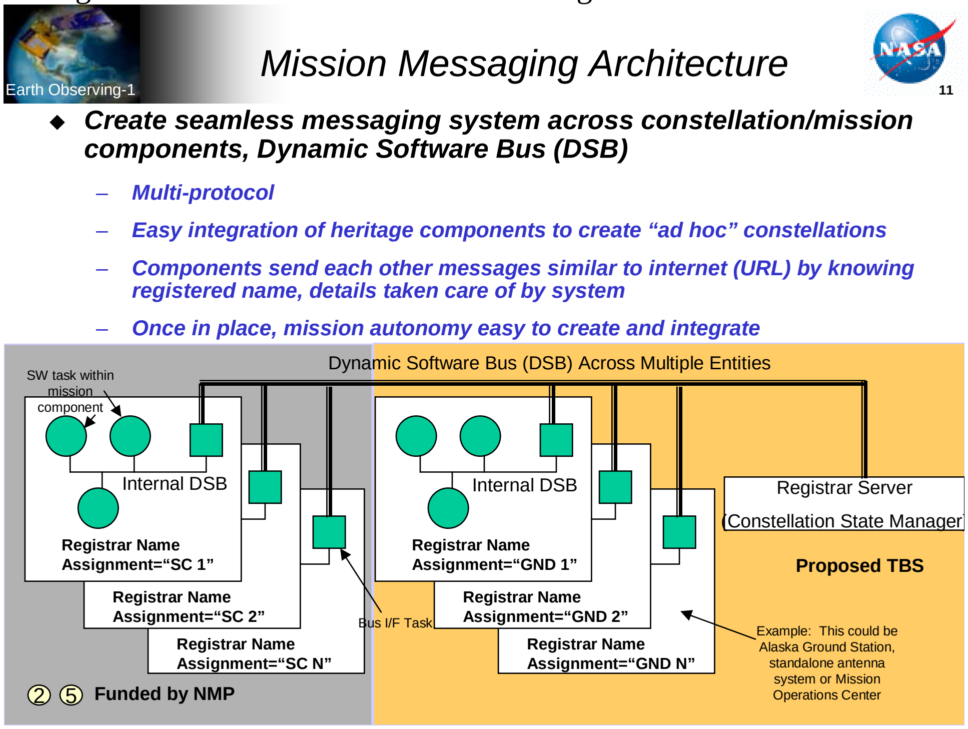
Onboard Processing
End-to-End Communications
Autonomous Coordination
Operational Testbed
Onboard Cloud Cover Detection Validation
① $180K(Complete)
AIST QRS
Preliminary EO-1 Autonomy Experiment
◆ Onboard planning
◆ Onboard feature detection
◆ Dynamic SW Bus
② $720K
Smart Antenna
◆ Ground phased array
◆ Cell tower com to sat
③ $1.1 Million
AIST NRA 2002
Sensorweb Testbed
◆ Test sensor web concepts on ground
$200K
④ RASC (Related effort)
Autonomous Science Experiment(ASE)
◆ Migration of ST6 onto EO-1
⑥ $ 3- 4 Million
EO-1, Terra, Aqua Sensorweb Demo 1 & 2
◆ Uses MODIS inst center to detect volcanoes
◆ Uses ASE to coord image
⑦ collect autonomously
no add funding for prelim expmnt
EO-1/ Gnd Sensor Sensorweb
◆ Sensors in Huntington Botanical Garden trigger
⑧ EO-1 image
no additional funding needed
Hyperspectral Compression WG
◆ Onboard data mining
◆ Onboard intelligent image compression
◆ Working group
Livingstone Onboard Model Based Diag Tool
◆ Autonomous anomaly diagnosis and recommendations
⑤ IS NRA Proposal
Intelligent Distributed Spacecraft Technology Testbed: NMP (JPL)
Related activity
Funded by ESTO
Funded by NMP
Funded by RASC
Proposed activity

Figure 1 EO-1 Testbed activities with color coding to indicate funding source or whether the activity is proposed

Figure 2 shows the conceptual layout of a mission-wide dynamic software bus. Color coding cross correlates activities related to figure 1.



Mission Messaging Architecture

- ***Create seamless messaging system across constellation/mission components, Dynamic Software Bus (DSB)***
  - *Multi-protocol*
  - *Easy integration of heritage components to create "ad hoc" constellations*
  - *Components send each other messages similar to internet (URL) by knowing registered name, details taken care of by system*
  - *Once in place, mission autonomy easy to create and integrate*

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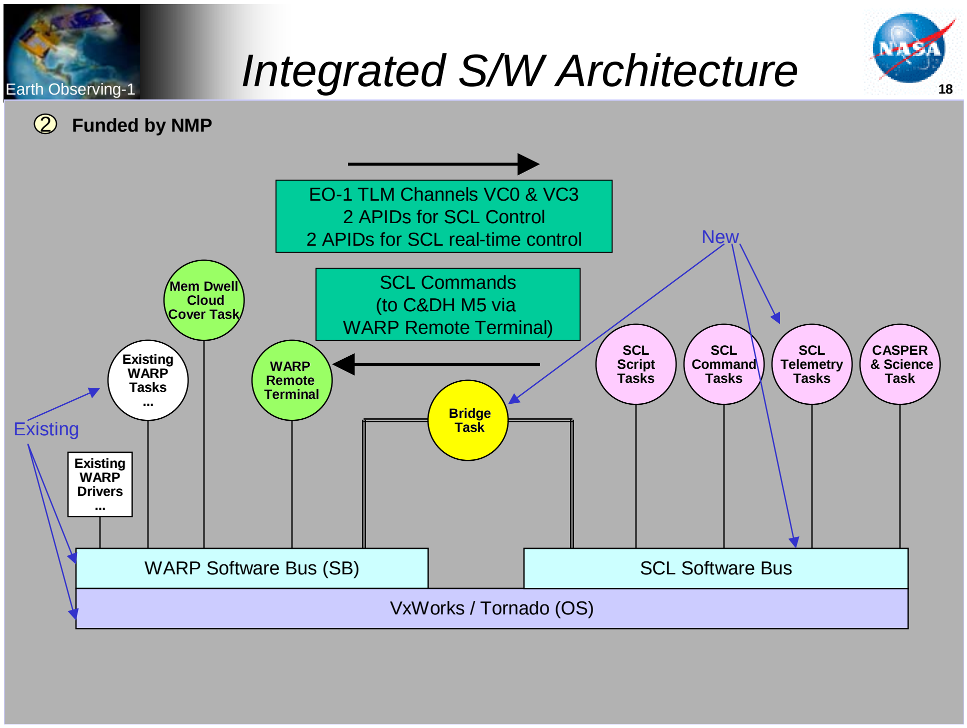
Dynamic Software Bus (DSB) Across Multiple Entities
SW task within mission component
Internal DSB
Registrar Name Assignment="SC 1"
Registrar Name Assignment="SC 2"
Registrar Name Assignment="SC N"
Bus I/F Task
Internal DSB
Registrar Name Assignment="GND 1"
Registrar Name Assignment="GND 2"
Registrar Name Assignment="GND N"
Registrar Server
(Constellation State Manager)
Proposed TBS
Example: This could be Alaska Ground Station, standalone antenna system or Mission Operations Center
② ⑤ Funded by NMP

Figure 2 Mission-wide messaging system to enable progressive autonomy



Earth Observing-1

Integrated S/W Architecture

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② Funded by NMP

EO-1 TLM Channels VC0 & VC3
2 APIDs for SCL Control
2 APIDs for SCL real-time control

SCL Commands
(to C&DH M5 via
WARP Remote Terminal)

New

Existing

Mem Dwell Cloud Cover Task

Existing WARP Tasks ...

WARP Remote Terminal

Bridge Task

SCL Script Tasks

SCL Command Tasks

SCL Telemetry Tasks

CASPER & Science Task

Existing WARP Drivers ...

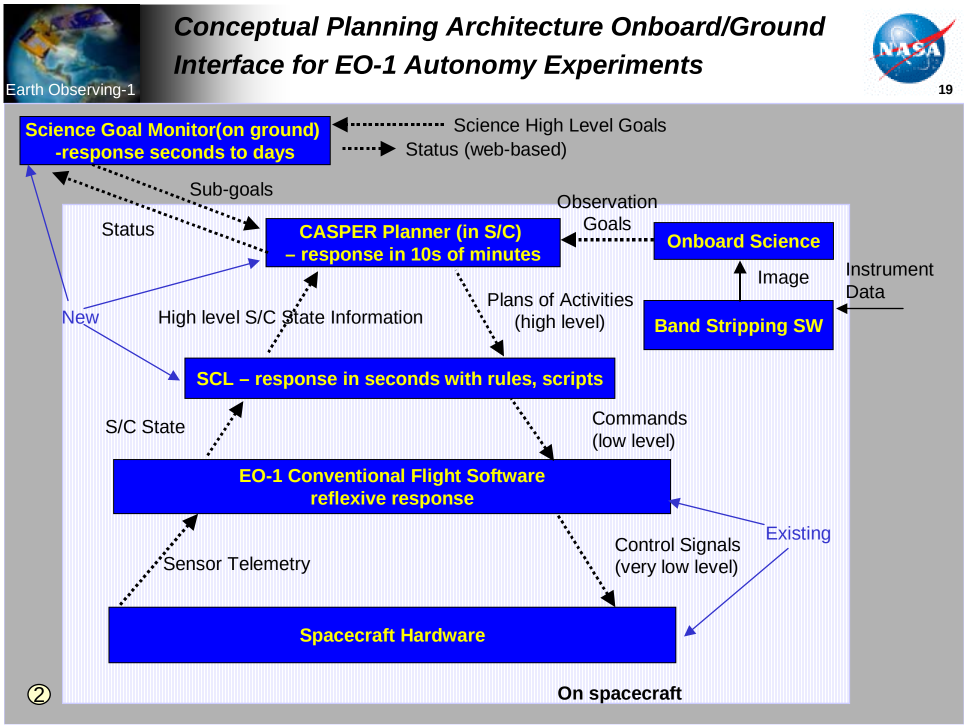
WARP Software Bus (SB)

SCL Software Bus

VxWorks / Tornado (OS)

Figure 3 Depicts how we are adding software to create a dynamic software bus on EO-1

Figure 3 shows how we are adding software to convert the EO-1 software bus into a dynamic software bus, being performed by Spacecraft Control language (SCL). The key capability is the ability to easily plug in new applications while EO-1 is on-orbit and having the EO-1 flight software recognize the software. Figure 4 shows the top level architecture of how we are "plugging-in" CASPER, the onboard planner into the dynamic



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Conceptual Planning Architecture Onboard/Ground Interface for EO-1 Autonomy Experiments

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Science Goal Monitor(on ground) -response seconds to days

Science High Level Goals

Status (web-based)

Sub-goals

Status

CASPER Planner (in S/C) – response in 10s of minutes

Observation Goals

Onboard Science

Image

Instrument Data

Band Stripping SW

New

High level S/C State Information

Plans of Activities (high level)

SCL – response in seconds with rules, scripts

S/C State

Commands (low level)

EO-1 Conventional Flight Software reflexive response

Existing

Sensor Telemetry

Control Signals (very low level)

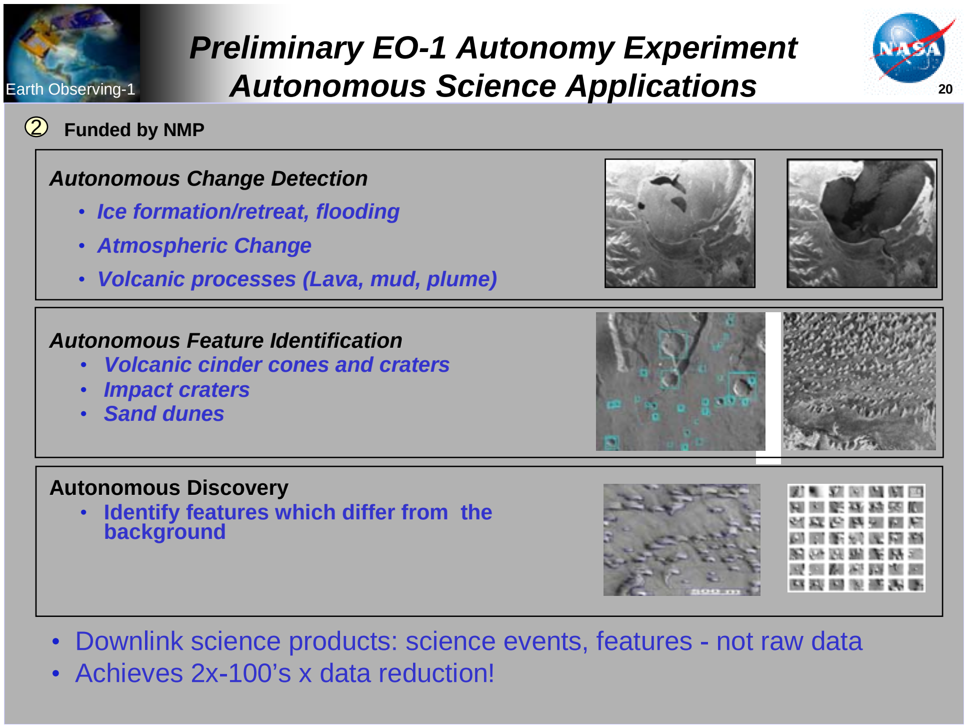
Spacecraft Hardware

②

On spacecraft

Figure 4 Depicts planning architecture being developed on top of dynamic software bus.

software bus.



Earth Observing-1

Preliminary EO-1 Autonomy Experiment
Autonomous Science Applications

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② Funded by NMP

Autonomous Change Detection

- *Ice formation/retreat, flooding*
- *Atmospheric Change*
- *Volcanic processes (Lava, mud, plume)*

Autonomous Feature Identification

- *Volcanic cinder cones and craters*
- *Impact craters*
- *Sand dunes*

Autonomous Discovery

- Identify features which differ from the background

- Downlink science products: science events, features - not raw data
- Achieves 2x-100's x data reduction!

Figure 5 Some of the planned types of experiments once CASPER installed on EO-1

Figure 5 is a representative set of types of experiments that will be conducted once the CASPRE system is installed on EO-1. Furthermore, once CASPER is onboard, we are attempting to run some rudimentary sensor web experiments whereby obwervations on EO-1 are triggered by some key MODIS instrument observation such as forest fires and volcanoes. EO-1 would be triggered to semi-autonomously trigger take a closer look. We are also working with someone at JPL to have an EO-1 observation be triggered by a ground sensor web if certain flood conditions occur.