National Aeronautics and Space Administration

Cyberinfrastructure for Aircraft Mission Support

Lawrence C. Freudinger

August 2010

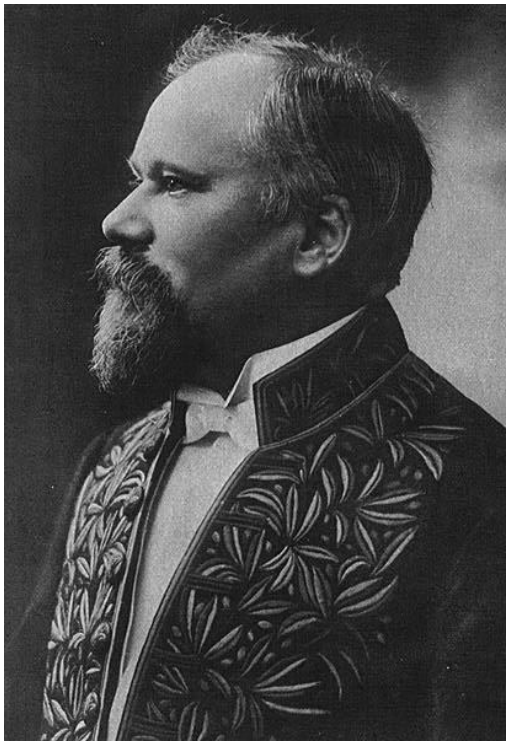
Outline

- Background and motivation
  - » The network is the *instrument*
- We've transformed the way one customer does business
  - » Network-enhanced airborne science field operations
  - » Increased productivity, situational awareness
- Seeking better, faster, cheaper
  - » Evolving toward enterprise-class web services oriented architecture for distributed testing

Observations on Observations

"Experiment is the sole source of truth. It alone can teach us something new. It alone can give us certainty."

Henri Poincaré, 1903



…but at what cost and how long does it take?

La Science et l'Hypothese. Flammarion, Paris, 1927. 1st . edition 1903. Science and Hypothesis (Dover) 1952 (p. 140)

Real Vision

"…to enable men and computers to *cooperate* in making decisions and controlling complex situations without inflexible dependence on predetermined programs"

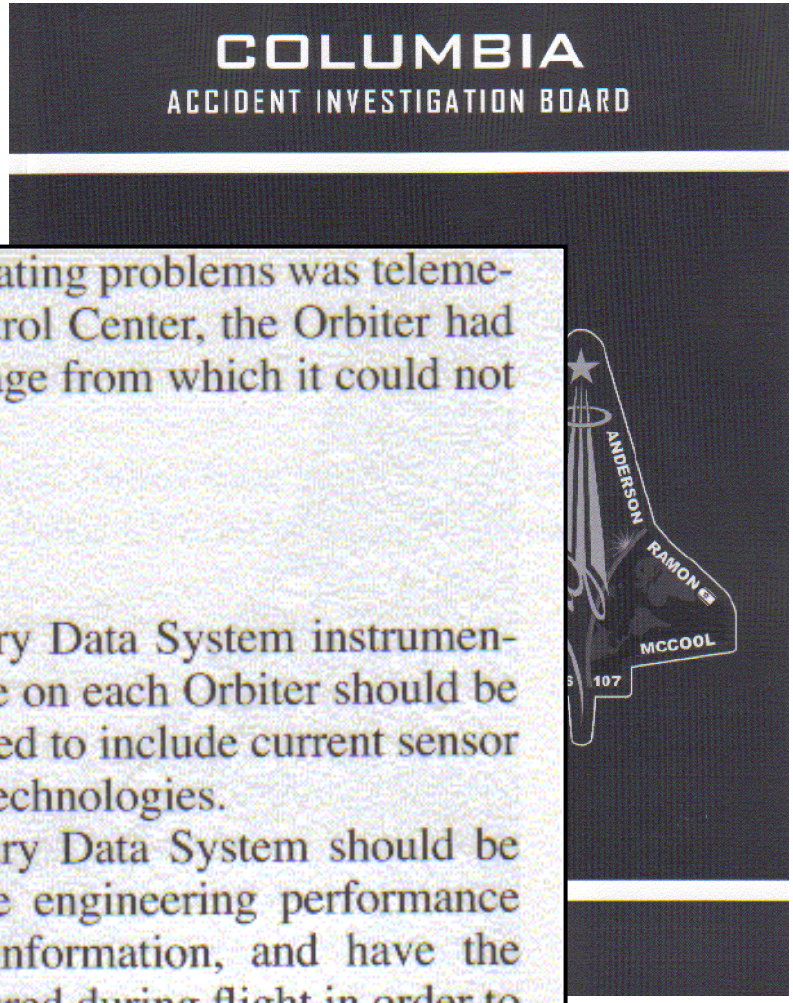
- J. C. R. Licklider, 1960

The lack of situational awareness causes lost opportunity.

Decision-support webs are the reason the Internet exists!!!

IRE Transactions on Human Factors in Electronics, volume HFE-1, pages 4-11, March 1960

Timely Situational Awareness is Everything



F3.6–5 By the time data indicating problems was telemetered to Mission Control Center, the Orbiter had already suffered damage from which it could not recover.

Recommendations:

R3.6-1 The Modular Auxiliary Data System instrumentation and sensor suite on each Orbiter should be maintained and updated to include current sensor and data acquisition technologies.

R3.6-2 The Modular Auxiliary Data System should be redesigned to include engineering performance and vehicle health information, and have the ability to be reconfigured during flight in order to allow certain data to be recorded, telemetered, or both, as needs change.

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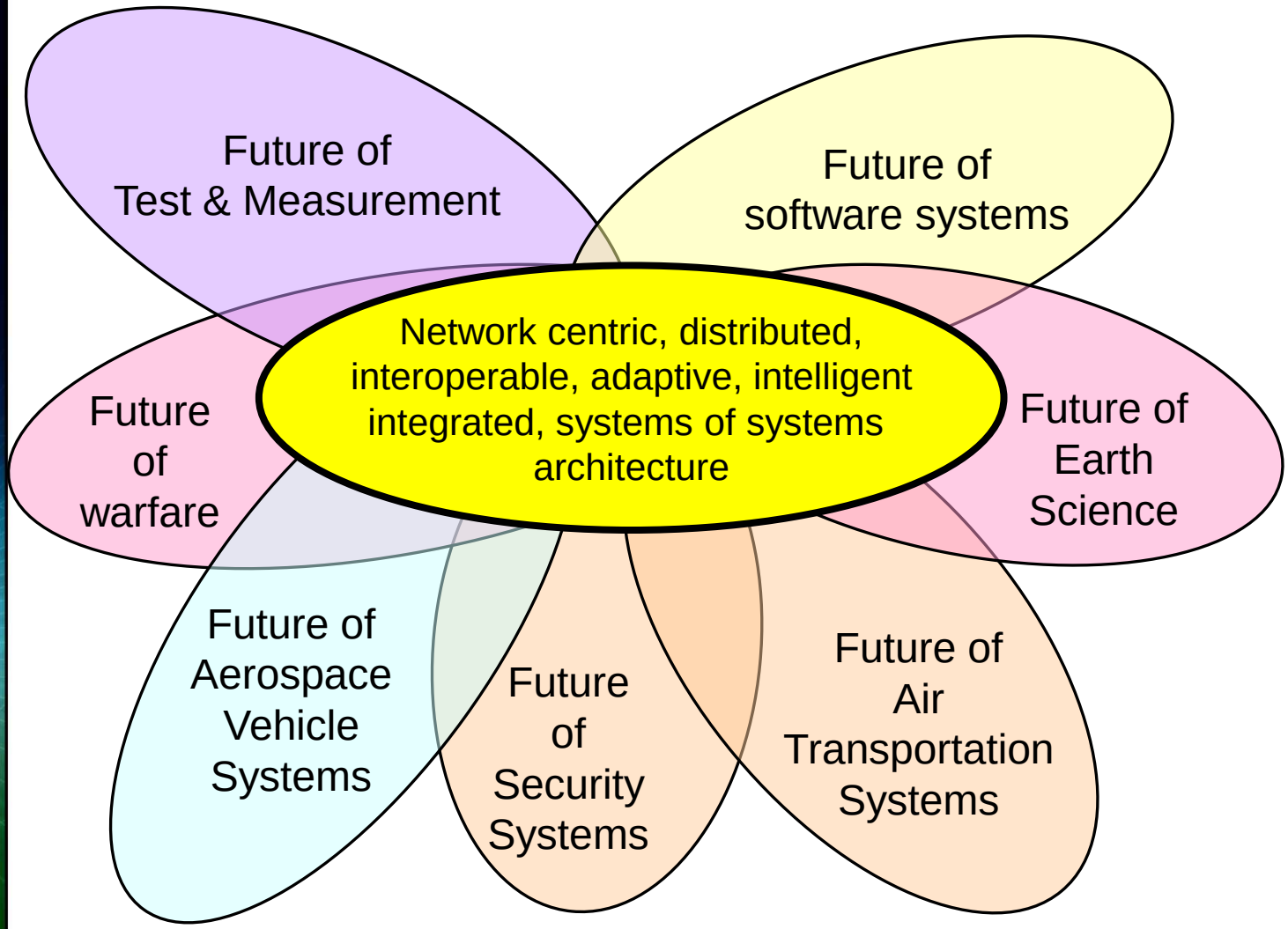
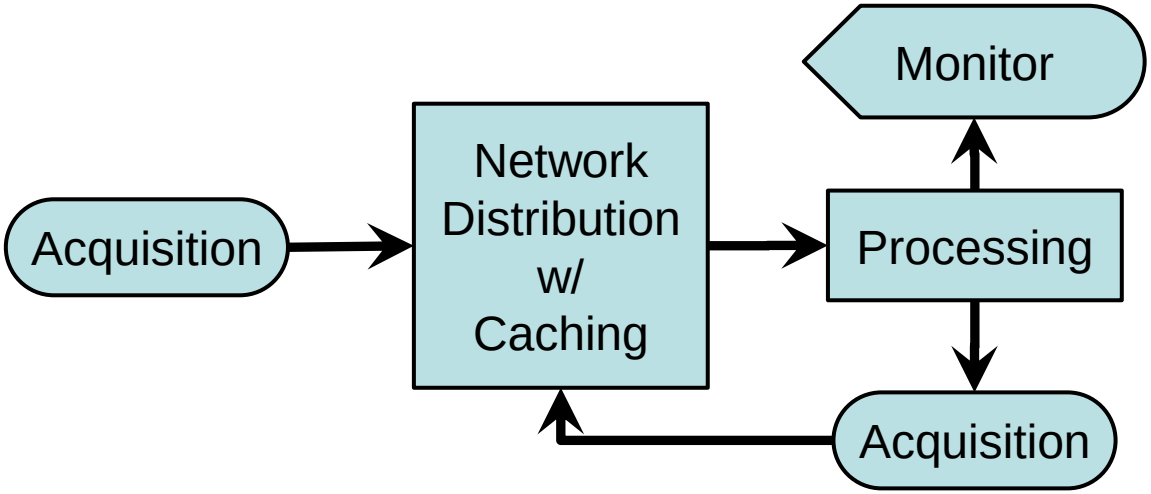
Technology Trends Reflect the Vision



Innovations: Closing Capability Gaps

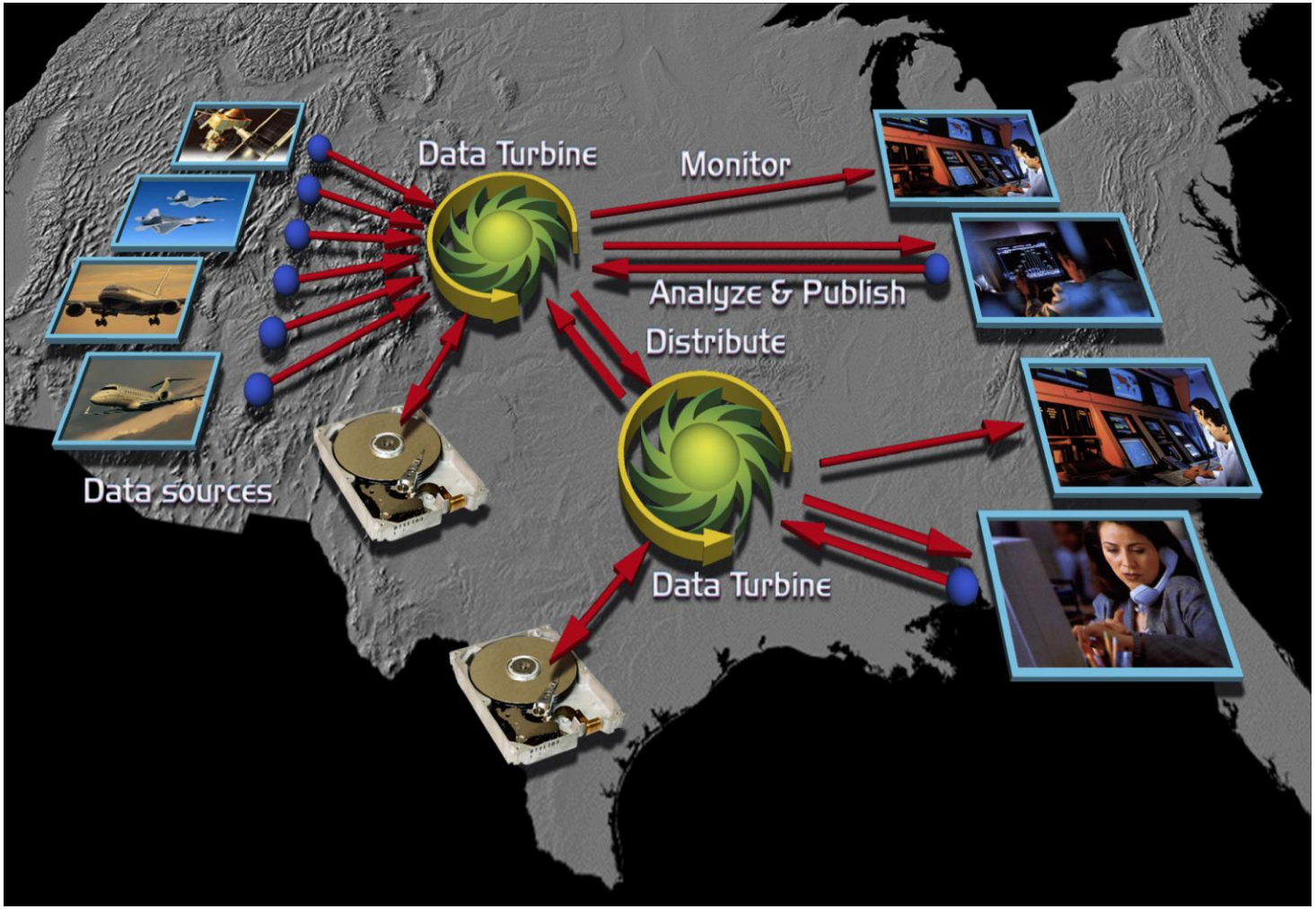
- Useful Middleware for Distributed Data Systems
  - » Ring Buffered Network Bus (RBNB) DataTurbine
- Network Gateways for Aircraft Payloads
  - » Research Environment for Vehicle Embedded Analysis on Linux (REVEAL)
- Web Applications for Mission Monitoring
  - » Realtime Mission Monitoring (RTMM)

The Network is the Instrument



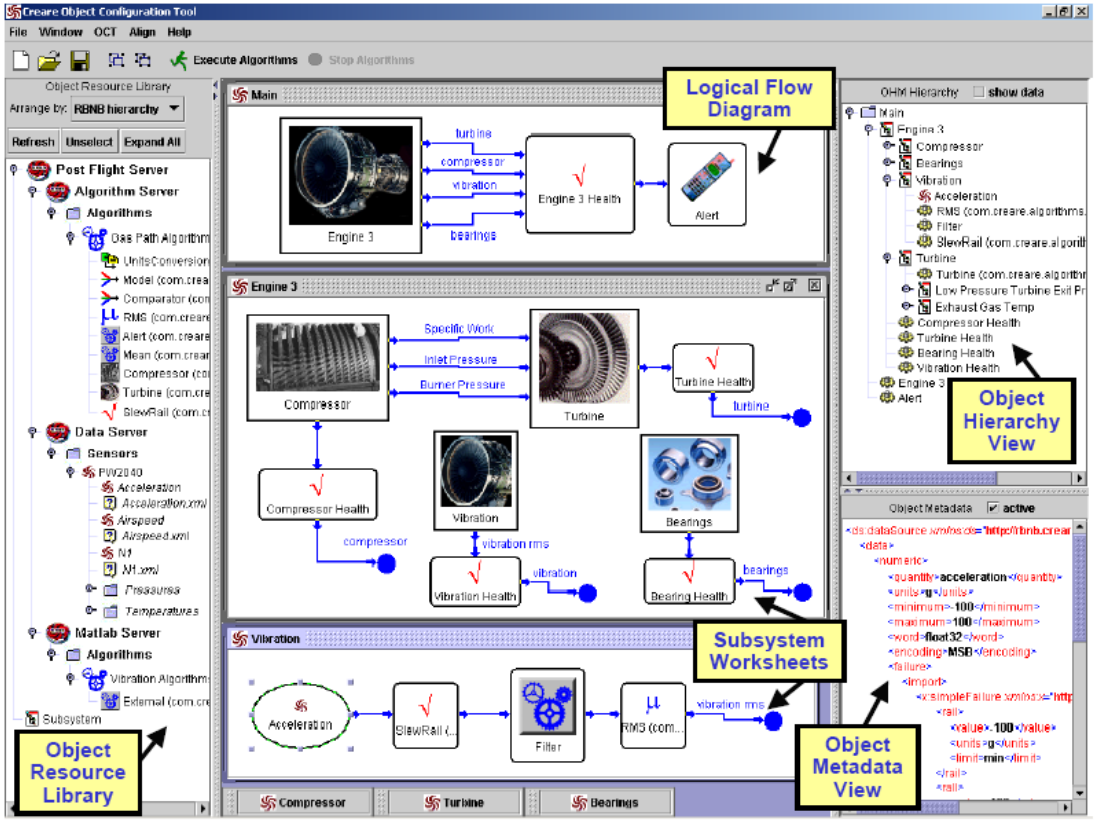
Loosely coupled
Distributed processes
Near realtime

A Web of Flight Data Recorders

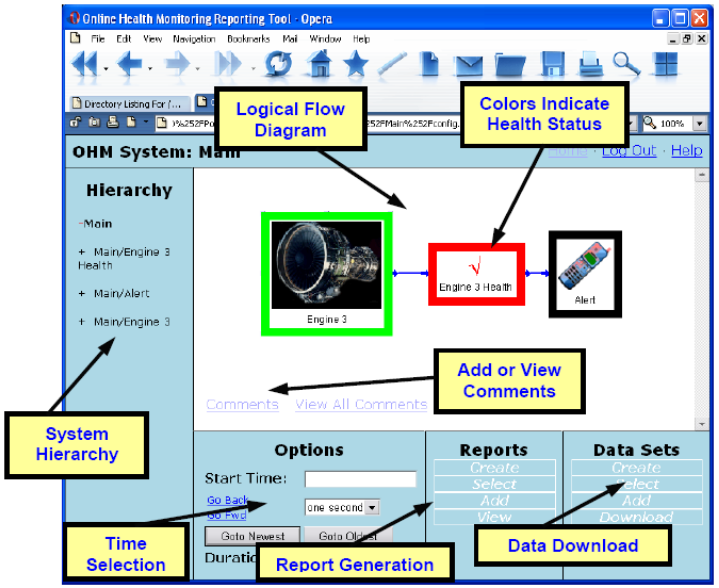


J. Zeitz/NASA

Example



Network-distributed application for web-based vehicle health monitoring (c. 2003)



Credit: Tony Dietz, Creare Inc (NASA SBIR)

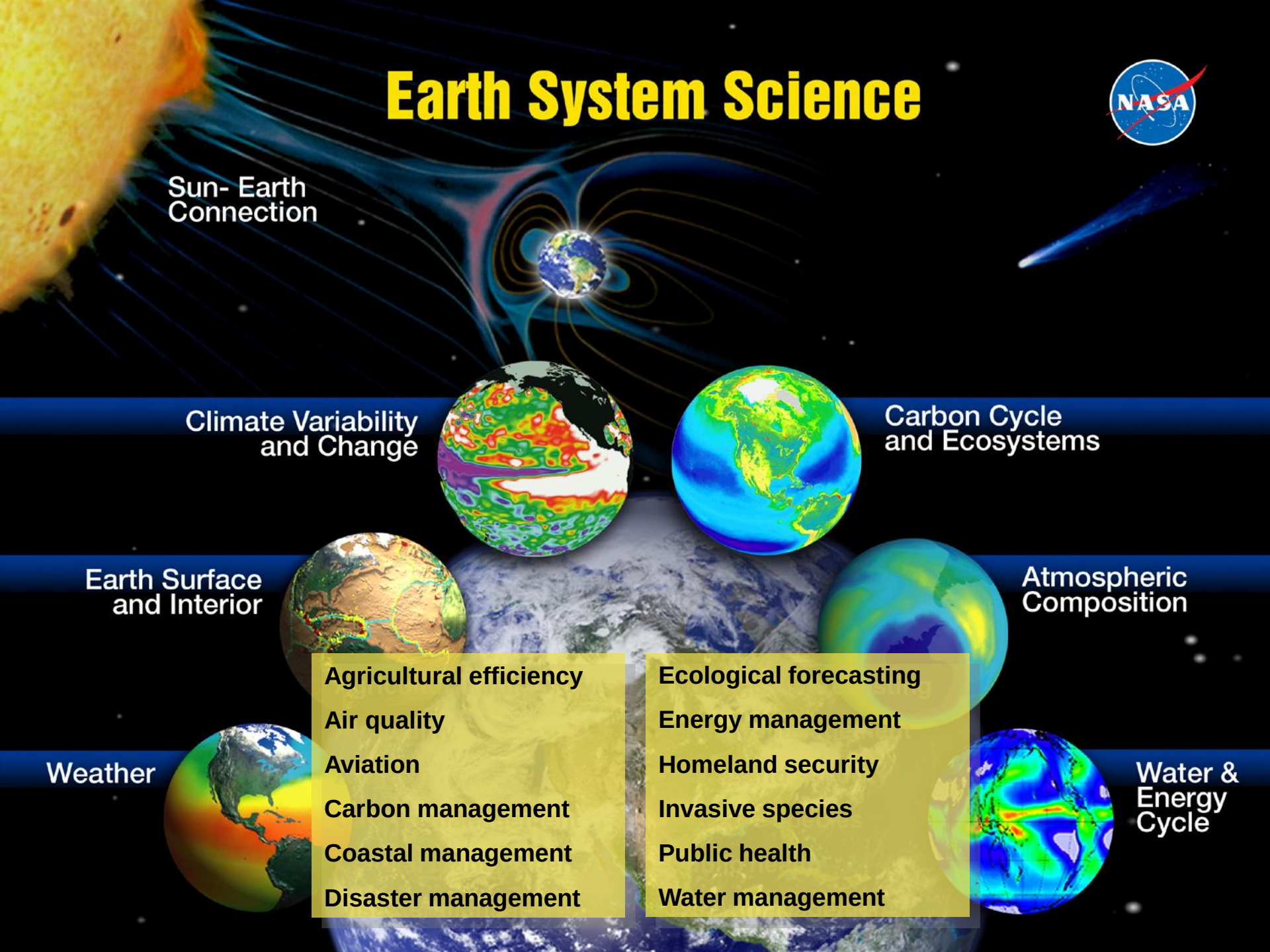
RBNB DataTurbine Summary

- A middleware innovation driven by aircraft testing needs
- NASA SBIR Program success story
- Now NSF-funded **open source** project
- Used worldwide, mostly in environmental observation applications
- Component in NASA's airborne science infrastructure

OPEN SOURCE DATA TURBINE INITIATIVE
Empowering the Scientific Community with Streaming Data Middleware

http://www.dataturbine.org/

Earth System Science



- Agricultural efficiency
- Air quality
- Aviation
- Carbon management
- Coastal management
- Disaster management
- Ecological forecasting
- Energy management
- Homeland security
- Invasive species
- Public health
- Water management


Vantage Points
Observation Capabilities
Inter-planetary Space
Cislunar Space
Earth Space
Near-Space
Airborne
Terrestrial
Solar System
Communications infrastructure and space/Mars; In situ observation Exploratory vehicles
Vision:
Intelligent, Affordable
Observation Systems
LEO/MEO
Active & passive sensors for trends & process studies
Suborbital
In situ measurement in research campaigns & validation of new remote sensors
Surface-Based Networks
Ocean buoys, air samplers, strain detectors, ground validation sites
Information Systems
Data management, data assimilation, modeling & synthesis

NASA's Airborne Science Fleet

NASA Core Aircraft

ER-2:
+ Read more

DC-8
+ Read more

WB-57
+ Read more

P-3B
+ Read more

G-III
+ Read more

Airborne Science Program Aircraft Catalog

Ikhana
+ Read more

Learjet 23 & 25
+ Read more

Twin Otter
+ Read more

B-200
+ Read more

S-3B
+ Read more

T-34C
+ Read more

Airborne Science Program New Technology Demonstrations

GlobalHawk
+ Read more

Sierra
+ Read more

Airborne Science Commercial Catalog

B-200
+ Read more

G-I
+ Read more

Learjet 24D
+ Read more

Viking 100, 300, 400
+ Read more

L-1011
+ Read more

Tarzan TD-1c
+ Read more

Cessna 402B
+ Read more

Piper Aztec
+ Read more

J-32
+ Read more

Aerosonde Mk4.4
+ Read more

Grob G-520 Egrett
+ Read more

Beechcraft Baron
+ Read more

Beechcraft A90, A100, A200
+ Read more

SAAB 340
+ Read more

OV-1
+ Read more

Super Ferret
+ Read more

Twin Otter
+ Read more

Piper Arrow
+ Read more

SkyJumper
+ Read more

Vector P
+ Read more

Aerosonde Mk4.3
+ Read more

F-104G&D
+ Read more

http://airbornescience.nasa.gov

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Research Environment for Vehicle Embedded Analysis on Linux (REVEAL)

- **Focus: Network Test/Measurement** (2000-2003)
  - » Need tool for sensor web R&D
- **Focus: Suborbital Science Needs** (2004-present)
  - » Needed greater capacity for useful work on UAVs
  - » Network-oriented payload integration, command, control, monitoring, CONOPS, etc. must emerge
  - » Squeeze more value out of every flight hour
- **REVEAL Innovation**
  - » Vehicle-independent interface for science instruments lowers costs and reduces risks
  - » Open standards; dynamically reconfigurable
  - » Traditional airborne laboratory support items in a small package (<20 lbs)
  - » Add affordable satcom for global-reach near realtime situational awareness
  - » Connect to terrestrial infrastructure

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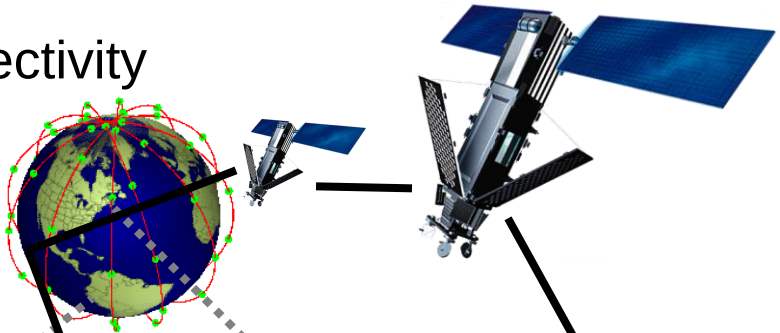
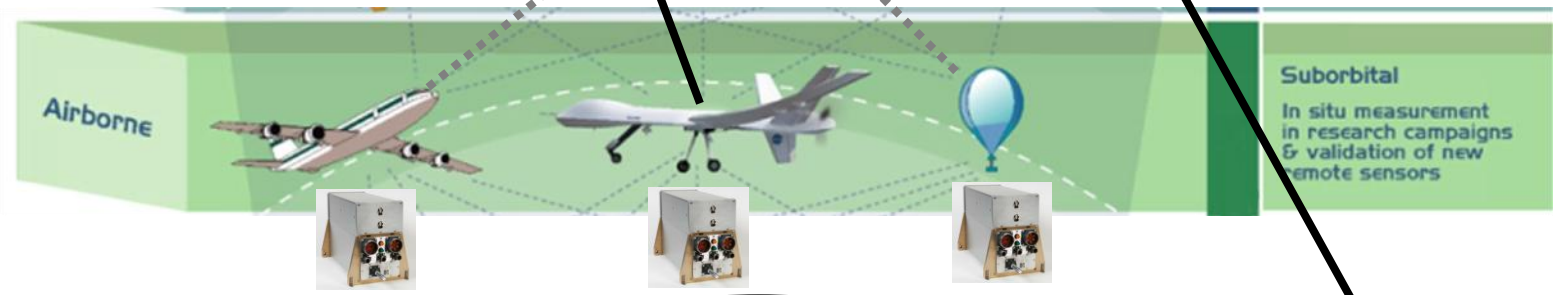
REVEAL Data System

Enabling Airborne Sensor Webs
By prototyping end-to-end connectivity

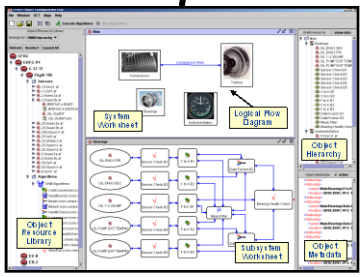


Global reach



Tele-Control

Tele-Observation

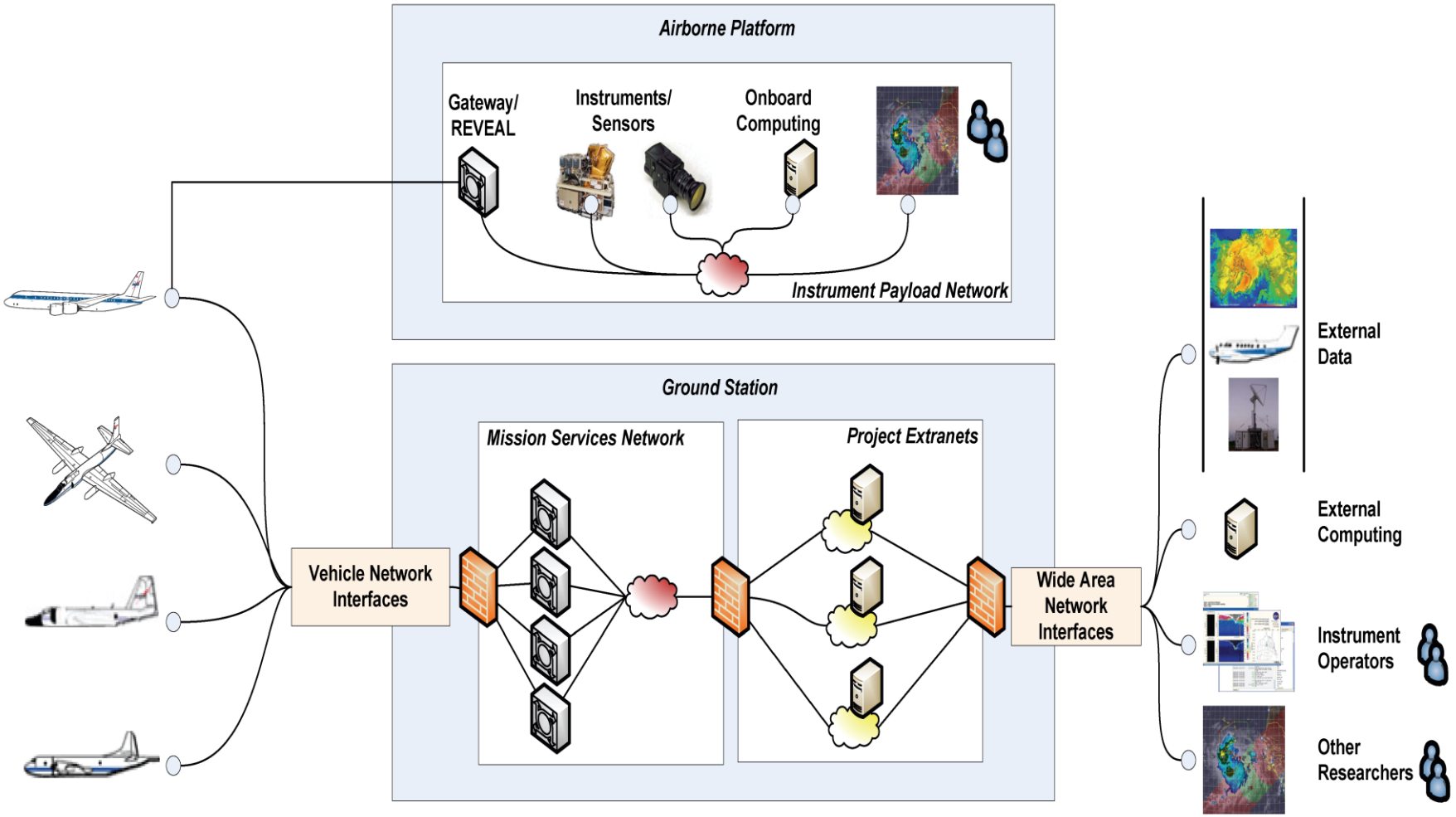


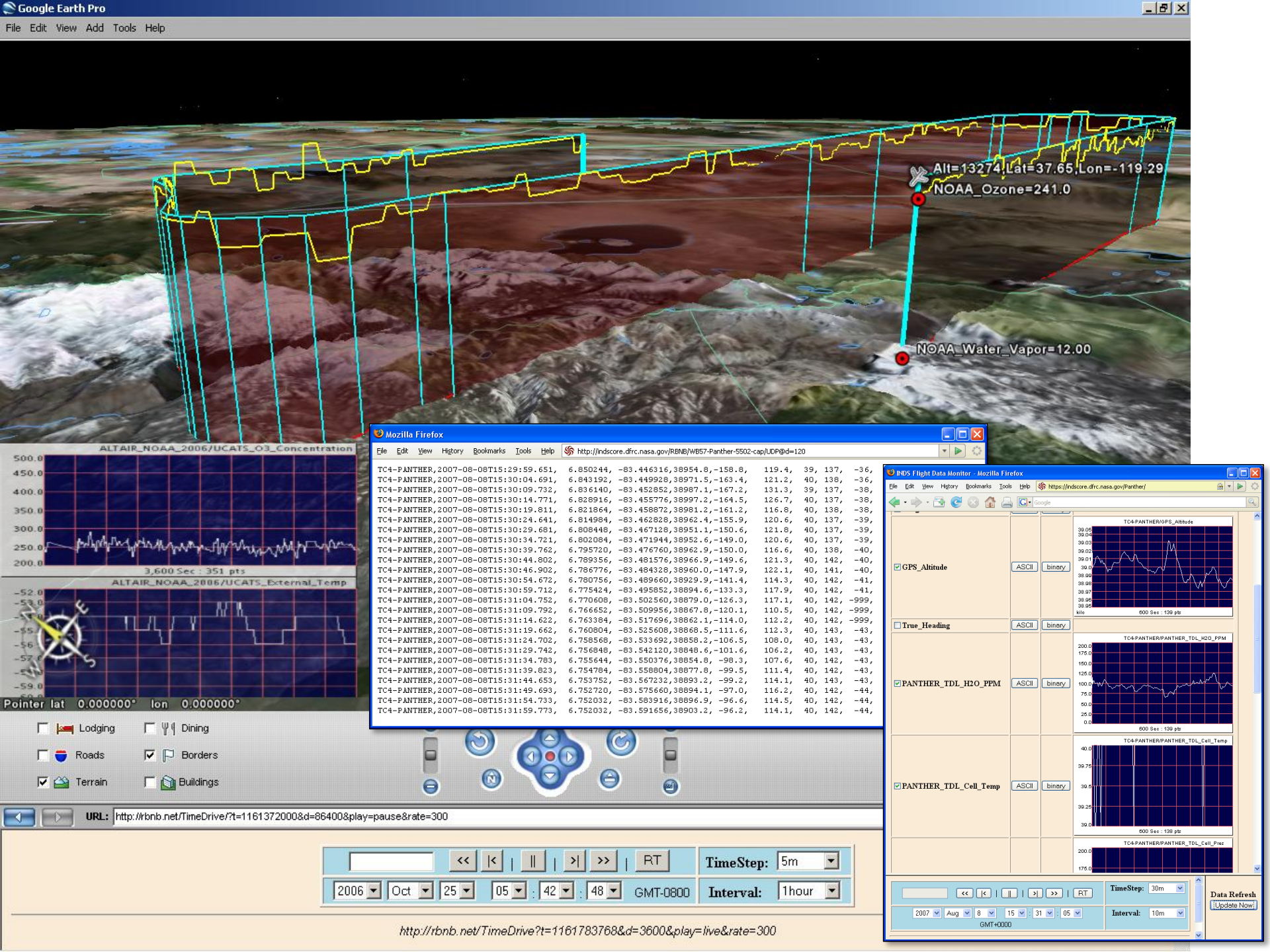
Tele-Computing

Dryden

Integration and distributed collaboration

Suborbital Telepresence Architecture (c. 2009)




Google Earth Pro
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NOAA_Water_Vapor=12.00
ALTAIR_NOAA_2006/UCATS_O3_Concentration
3,600 Sec : 351 pts
ALTAIR_NOAA_2006/UCATS_External_Temp
Pointer lat 0.000000° lon 0.000000°
Lodging
Dining
Roads
Borders
Terrain
Buildings
Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://indscore.dfrc.nasa.gov/RBNB/WB57-Panther-5502-cap/UDP@d=120
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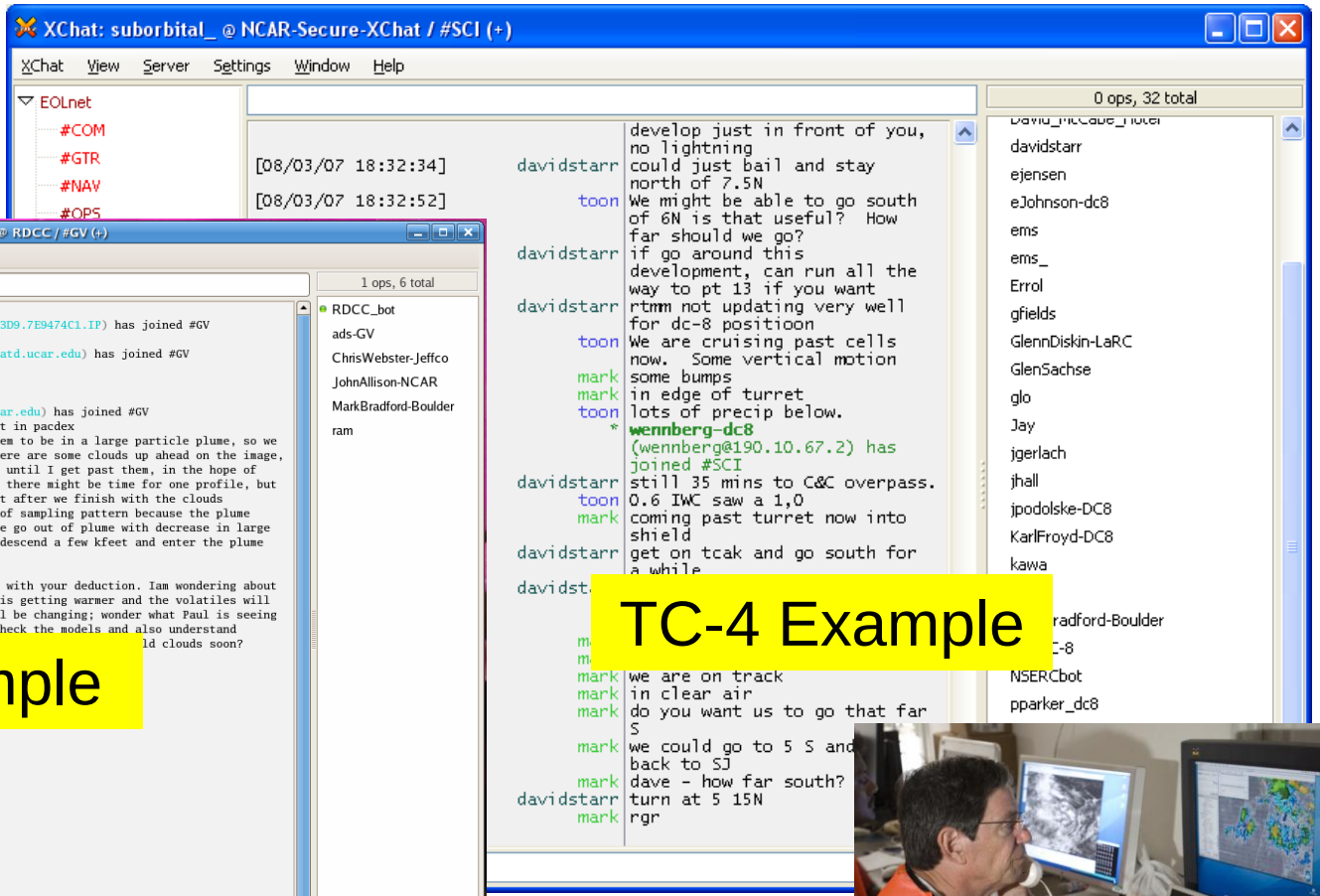
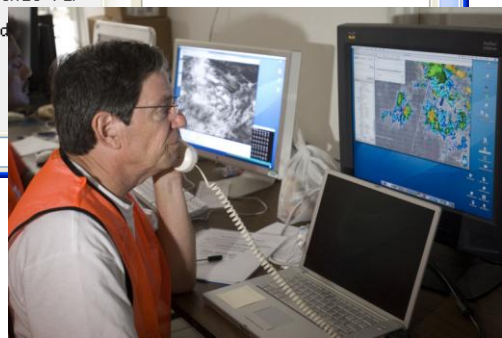
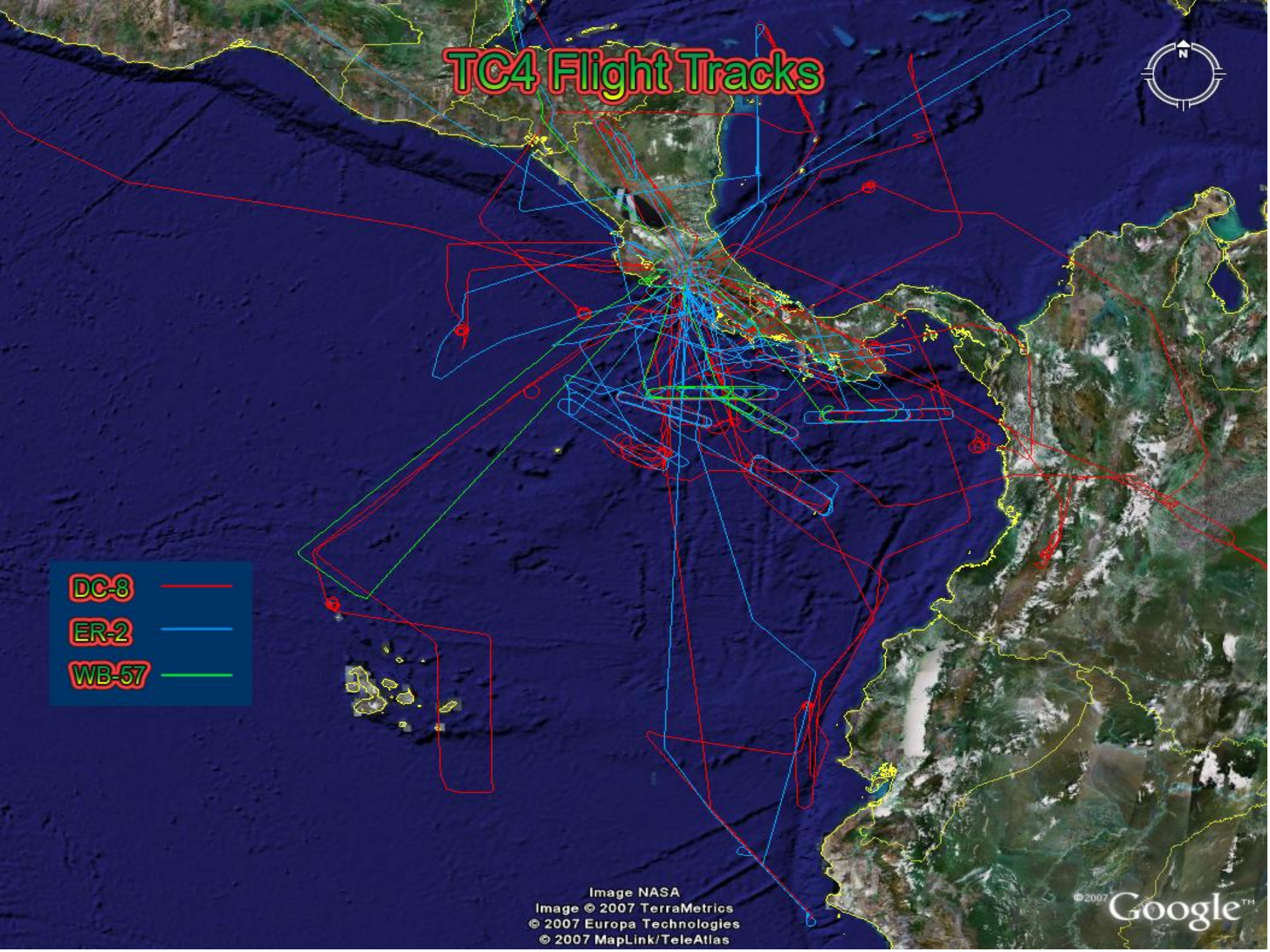
GPS_Altitude
True_Heading
PANTHER_TDL_H2O_PPM
PANTHER_TDL_Cell_Temp
ASCII
binary
URL: http://rbnb.net/TimeDrive/?t=1161372000&d=86400&play=pause&rate=300
RT
TimeStep: 5m
2006 Oct 25 05 : 42 : 48 GMT-0800
Interval: 1hour
http://rbnb.net/TimeDrive?t=1161783768&d=3600&play=live&rate=300
TimeStep: 30m
Interval: 10m
Data Refresh
Update Now!

Interagency Network Chat is a Useful Service

Secure IRC Chat Server at NCAR emerged as *de facto* community-wide service






TC4 Flight Tracks
DC-8
ER-2
WB-57
Image NASA
Image © 2007 TerraMetrics
© 2007 Europa Technologies
© 2007 MapLink/TeleAtlas
©2007 Google™

Realtime Mission Monitor (RTMM)

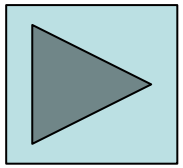
"Making Science Easier"

- Pre-flight planning
  - » Model and forecast fields
  - » Satellite overpass predicts
  - » Waypoint Planning Tool
- In-flight monitoring and operations management strategies
  - » Operations center focal point
  - » Current weather conditions
  - » Plane-to-plane data transfer
- Post-flight analyses, research, and assessments
  - » Encapsulate and replay missions

Monitoring the flights on the "big screen" during TC4

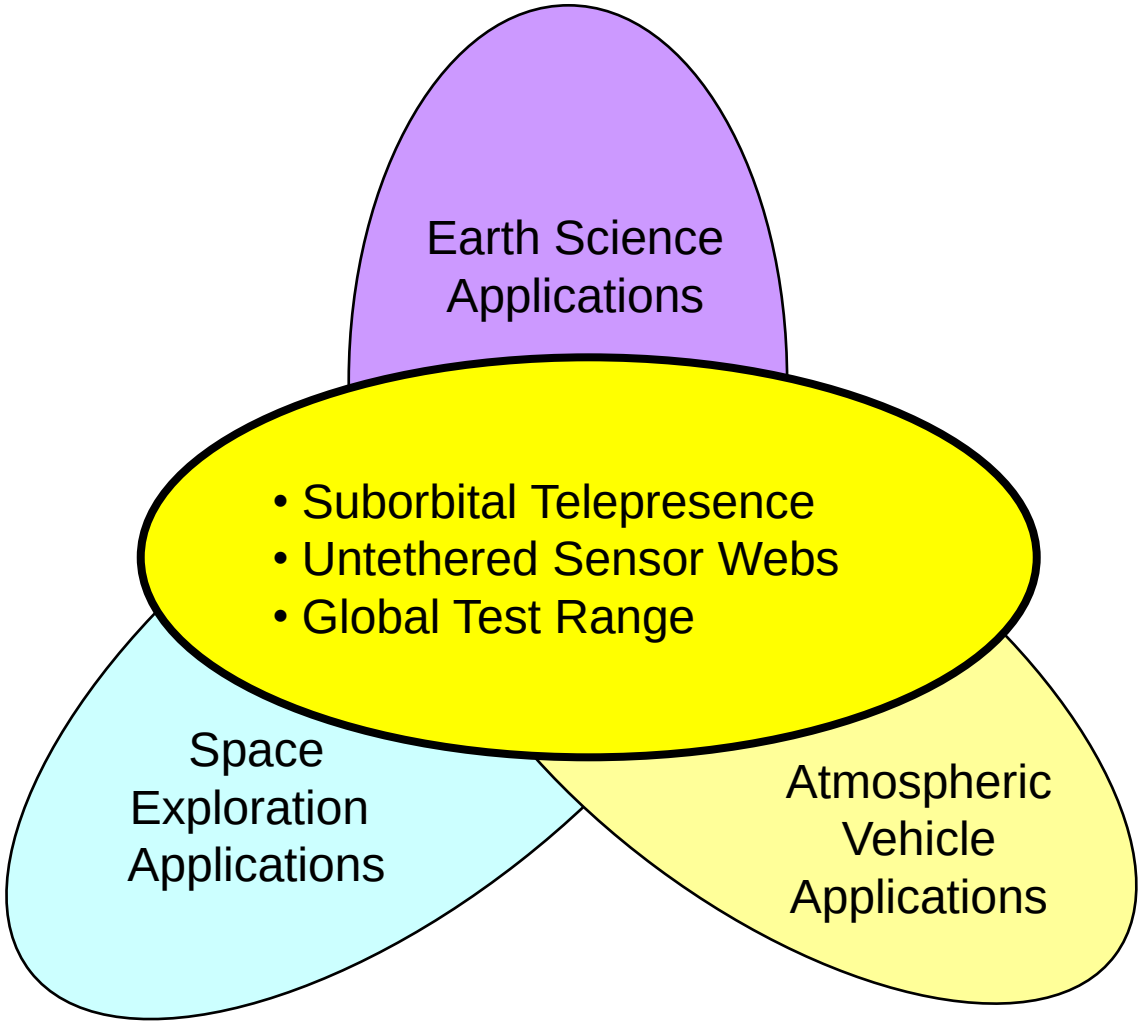
Credit: NASA Marshall Space Flight Center

Video clip

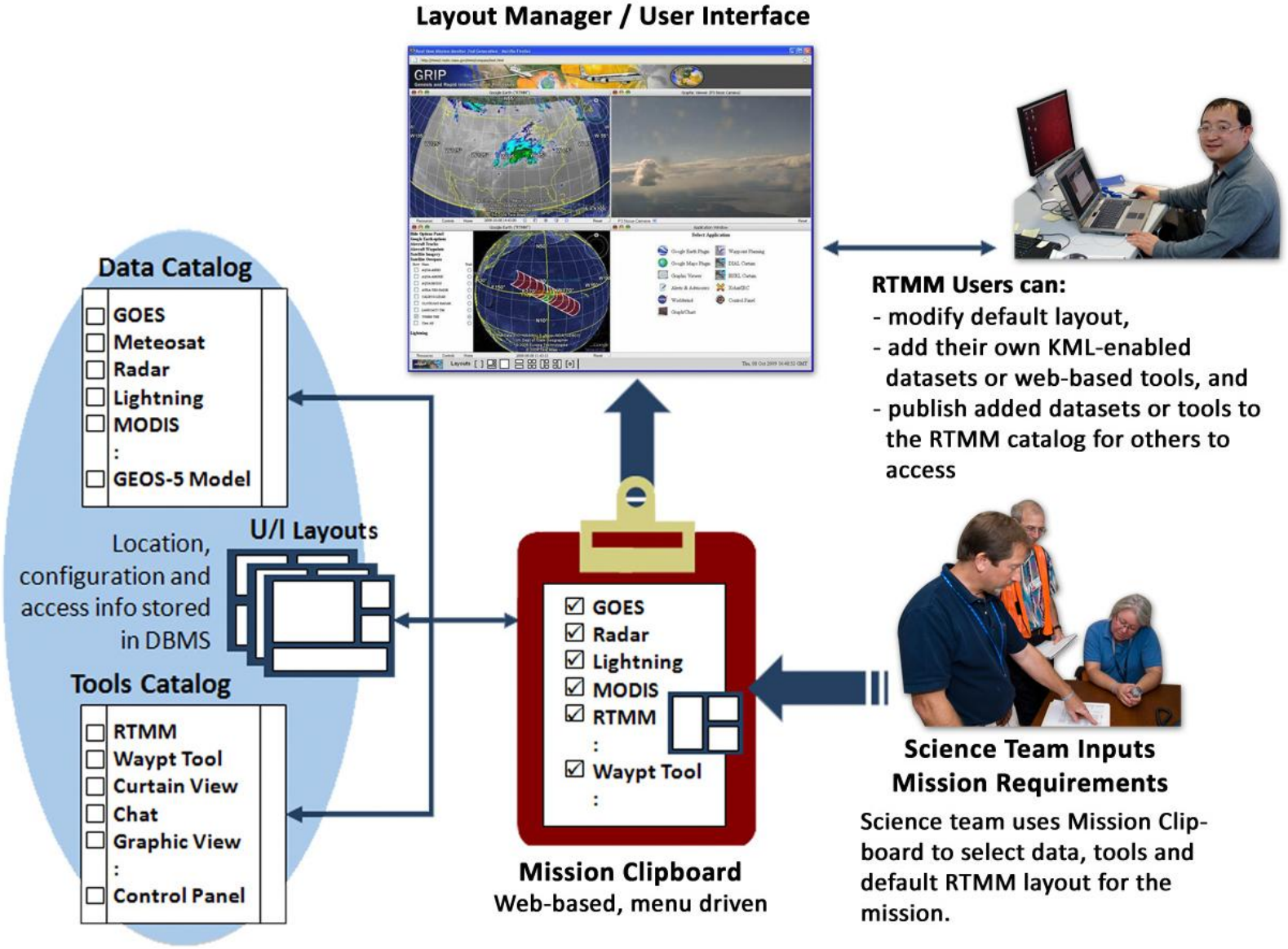


http://rtmm.nsstc.nasa.gov/movies-arctas.html

Toward Enterprise-Class Services



RTMM 2nd Generation Concept

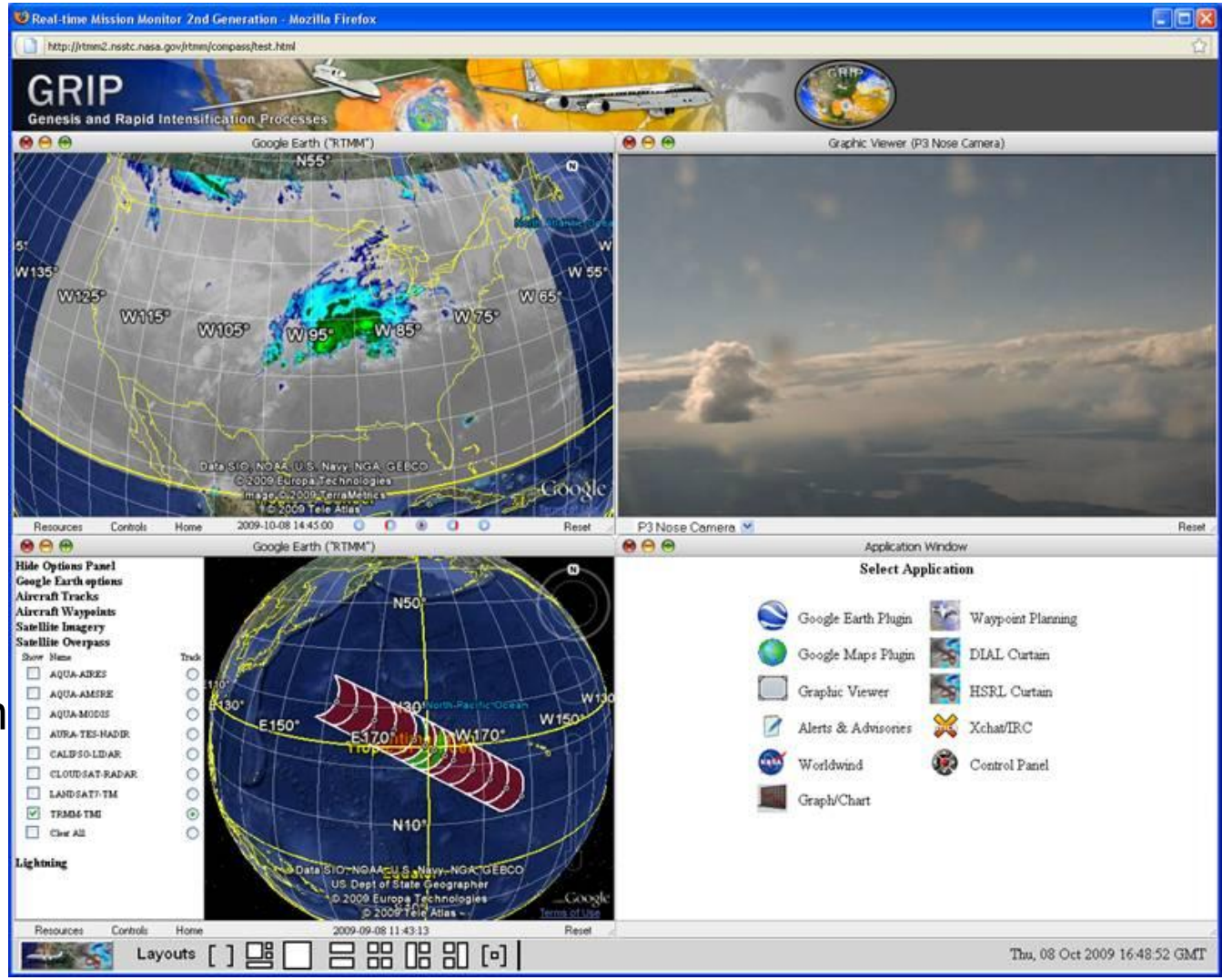


Credit: NASA Marshall Space Flight Center

2nd Generation User Interface

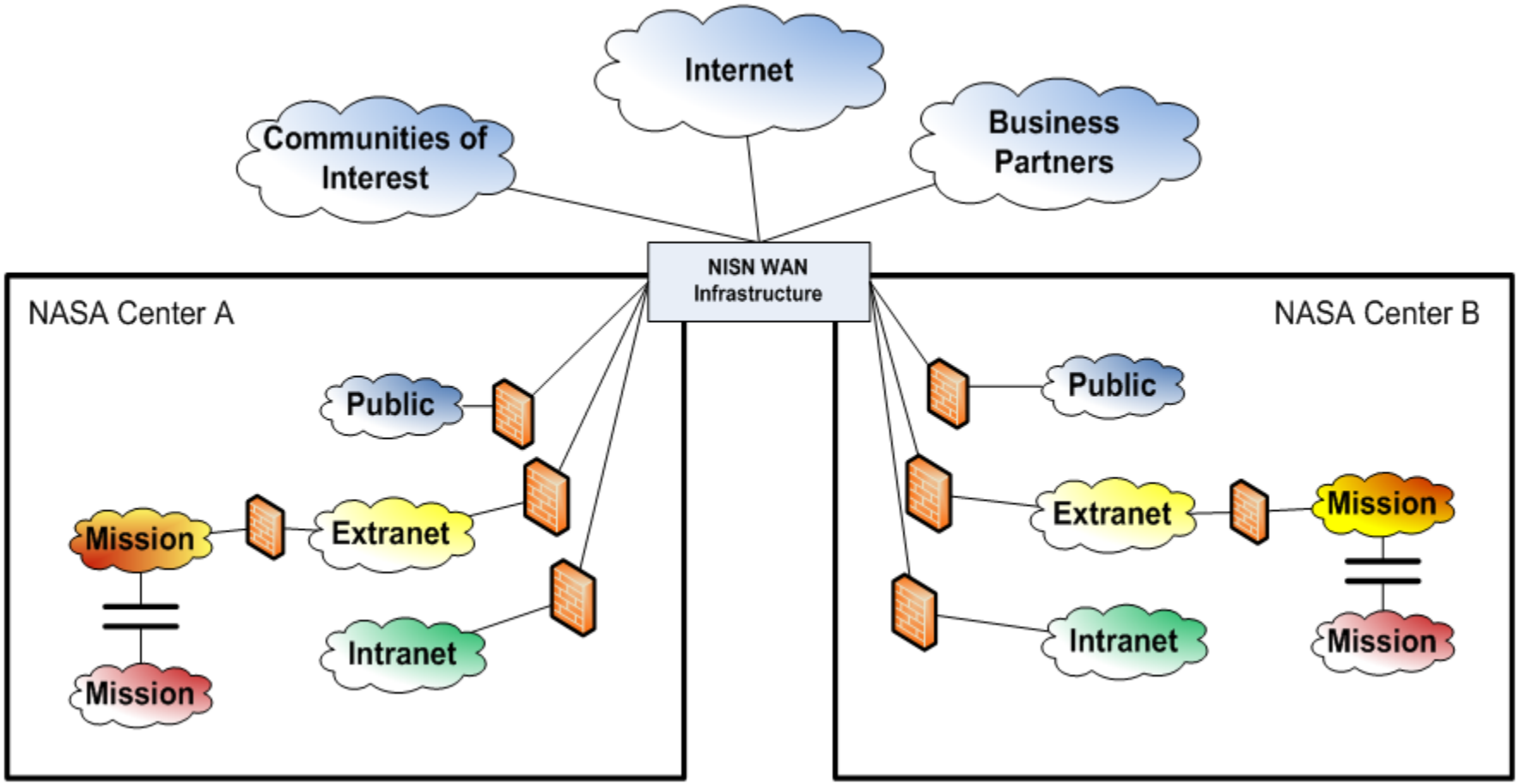
"Making RTMM Better"

- Multiple windows within the interface to support multi-tasking using different RTMM tools
- Many different layouts possible
- Easily configured
- Default mission configuration and individual user's customizations can be saved across sessions

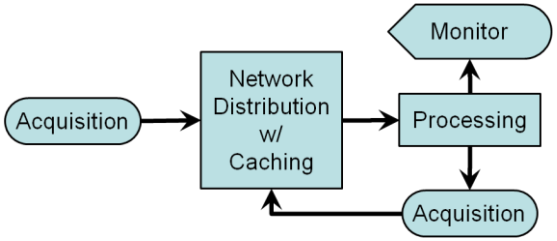


Credit: NASA Marshall Space Flight Center

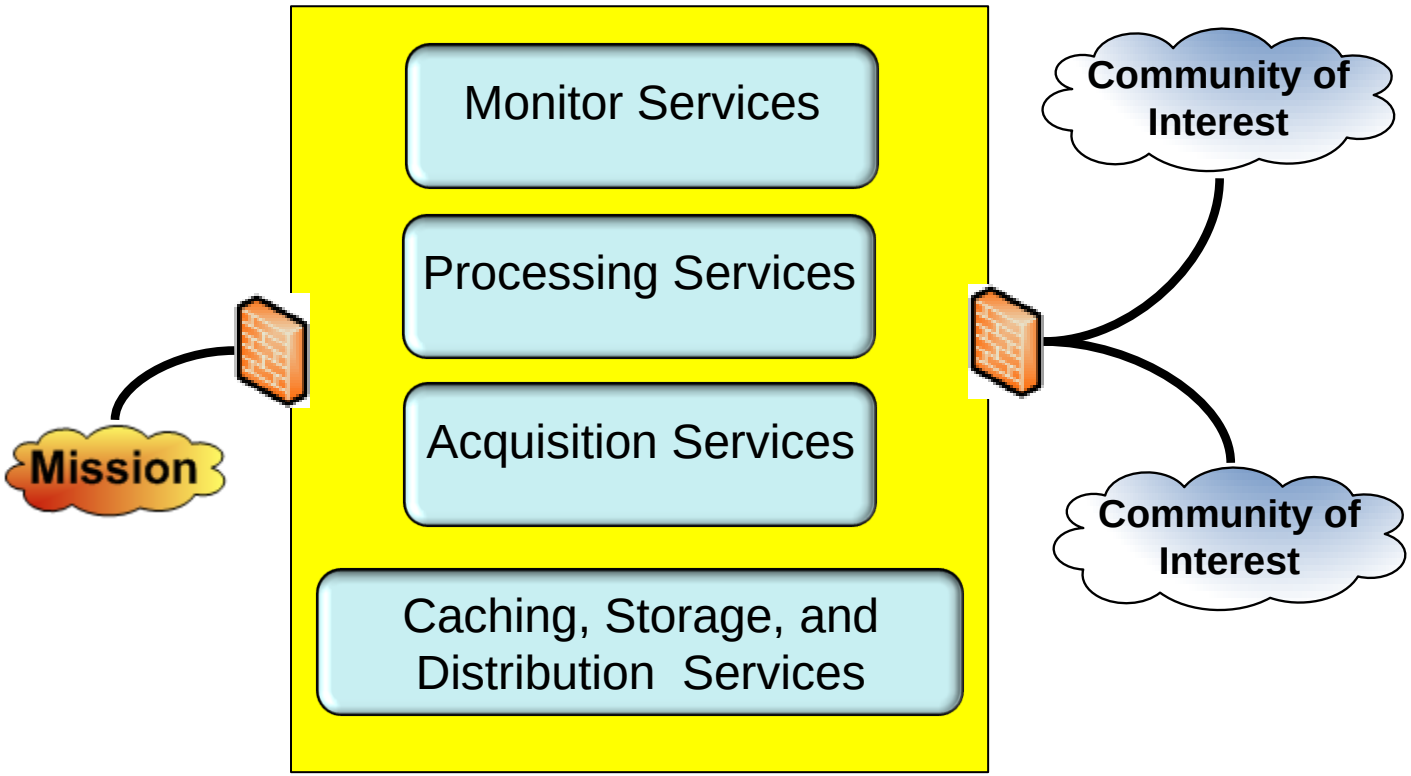
Toward Enterprise Architecture



The Network is the Instrument



The extranet is where these web services live



COMPASS

- The Airborne Science Program targets an enterprise-scale set of services called COMPASS (Common Operations Management Portal for Airborne Science Systems)
  - » Central location for situational awareness
  - » Calendars, notification, resource tracking
  - » Scheduling, collaboration/coordination
  - » Documentation, wiki/blog
  - » Configurability for different user classes
- The service-oriented architecture for distributed systems is the foundation

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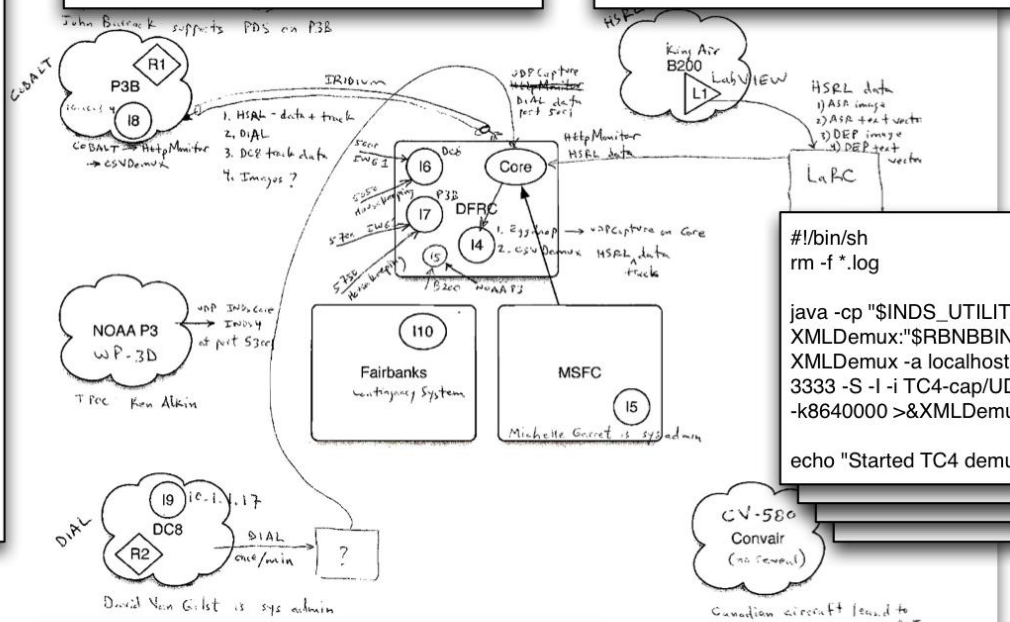
"Distributed" Can be Confusing

```
#! /bin/sh

pushd Server
./startup.sh
popd

sleep 15

pushd Archives
./startup.sh
popd

pushd Capture
./startup.sh
popd

pushd Jobs
./startup.sh
popd

sleep 5
pushd Projects
./startup.sh
popd

echo "Started
Projects"
```

```
ECHO OFF
CD C:\INDS
START "RBNB Server" /DServer /MIN startup.bat
START "Archives" /DArchives /MIN startup.bat
START "Capture" /DCapture /MIN startup.bat
START "Jobs" /DJobs /MIN startup.bat
START "Projects" /DProjects /MIN startup.bat
ECHO Started Projects
```

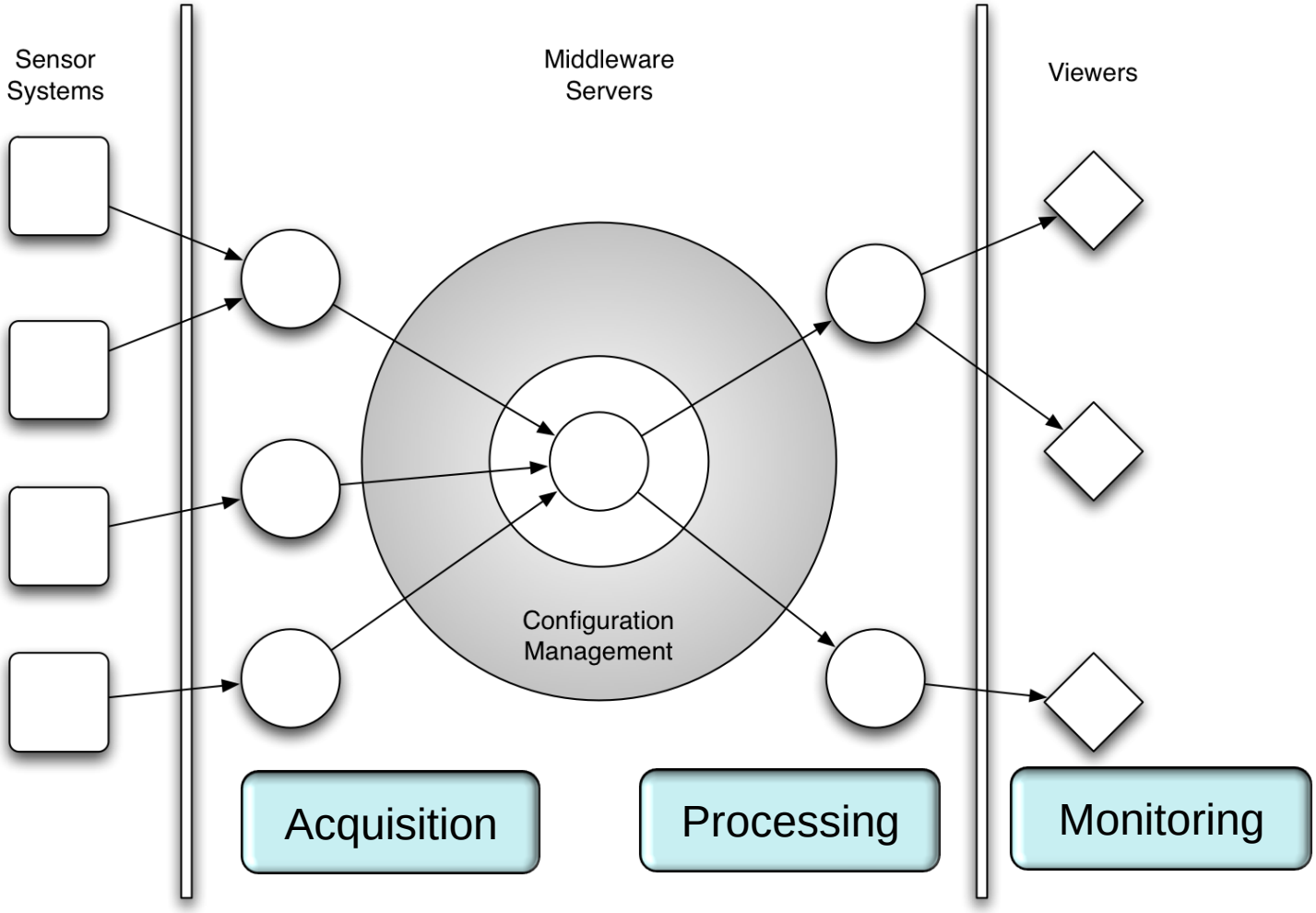
```
# Start TrackKMLPlugIn
java -cp "$RBNBPI":"$RBNBBIN"/rbnb.jar TrackKMLPlugIn
-g -s -C -f ./TrackKMLConfig.txt >& TrackKML.log &
```




```
#!/bin/sh
rm -f *.log

java -cp "$INDS_UTILITY"/
XMLDemux:"$RBNBBIN"/rbnb.jar
XMLDemux -a localhost:3333 -A localhost:
3333 -S -I -i TC4-cap/UDP -x TC4.xml -c10
-k8640000 >&XMLDemux_TC4.log  &

echo "Started TC4 demux"
```

```
START "UDPCapture RDCC SCI Channel on 35001" /MIN
java -cp %INDS_UTILITY%\UDPCapture;%RBNBBIN%
\rbnb.jar UDPCapture -s 35001 -k 1000000 -nRDCC-SCI

START "UDPCapture RDCC DC8 Channel on 35002" /MIN
java -cp %INDS_UTILITY%\UDPCapture;%RBNBBIN%
\rbnb.jar UDPCapture -s 35002 -k 1000000 -nRDCC-DC8
```

Service Management Tools Needed



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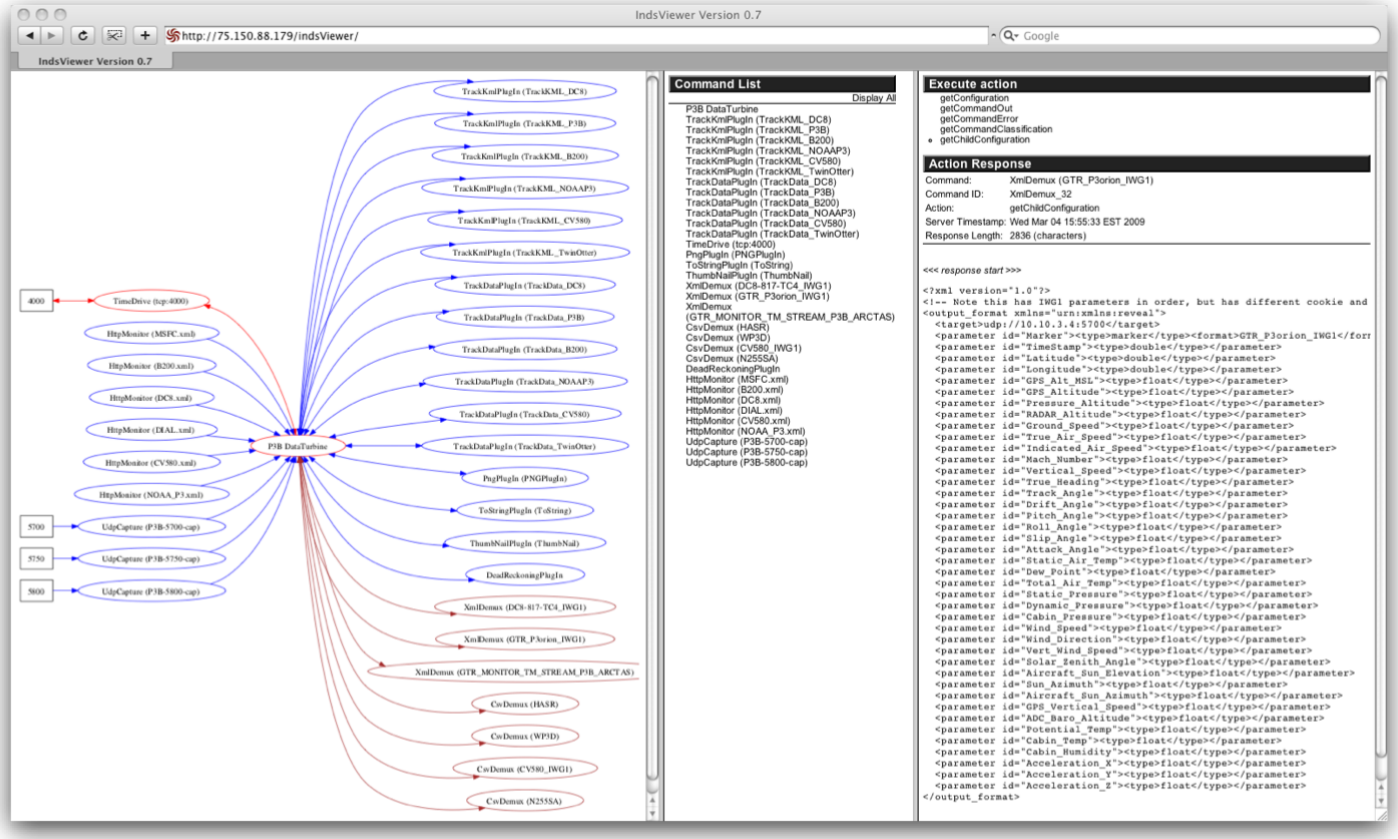
A Service Management Interface



Scalable, distributed, virtual data systems
Suitable for enterprise clouds

Concluding Comments

- We've transformed the approach to field operations for airborne science
- Just first spiral of real-life mission support services
- Cyberinfrastructure leveraged open source software, network transport over satellite, and geographically distributed resources
- Ongoing work targets service oriented enterprise architecture and increasing role for cloud computing

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QUESTIONS?