Cyberinfrastructure for Aircraft Mission Support

Lawrence C. Freudinger
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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?

**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.
Technology Trends Reflect the Vision

Future of Test & Measurement

Future of software systems

Future of warfare

Future of Earth Science

Future of Aerospace Vehicle Systems

Future of Air Transportation Systems

Future of Security Systems

Network centric, distributed, interoperable, adaptive, intelligent integrated, systems of systems architecture
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

Acquisition -> Network Distribution w/ Caching -> Processing

Monitor

Acquisition

Loosely coupled
Distributed processes
Near realtime
A Web of Flight Data Recorders
Example

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

http://www.dataturbine.org/
Earth System Science

- Sun-Earth Connection
- Climate Variability and Change
- Earth Surface and Interior
- Atmospheric Composition
- Weather
- Carbon Cycle and Ecosystems
- Water & Energy Cycle

Topics:
- Agricultural efficiency
- Air quality
- Aviation
- Carbon management
- Coastal management
- Disaster management
- Ecological forecasting
- Energy management
- Homeland security
- Invasive species
- Public health
- Water management
Vision: Intelligent, Affordable Observation Systems
Research Environment for Vehicle Embedded Analysis on Linux (REVEAL)

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

Global reach

Integration and distributed collaboration

Tele-Control

Tele-Observation

Tele-Computing

Dryden
Suborbital Telepresence Architecture (c. 2009)
Interagency Network Chat is a Useful Service

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

- Suborbital Telepresence
- Untethered Sensor Webs
- Global Test Range
RTMM 2nd Generation Concept

Layout Manager / User Interface

Data Catalog
- GOES
- Meteosat
- Radar
- Lightning
- MODIS
- GEOS-5 Model

Location, configuration and access info stored in DBMS

Tools Catalog
- RTMM
- Waypt Tool
- Curtain View
- Chat
- Graphic View
- Control Panel

U/I Layouts

Mission Clipboard
Web-based, menu driven

RTMM Users can:
- modify default layout,
- add their own KML-enabled datasets or web-based tools, and
- publish added datasets or tools to the RTMM catalog for others to access

Science Team Inputs Mission Requirements
Science team uses Mission Clipboard to select data, tools and default RTMM layout for the mission.

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
“Distributed” Can be Confusing
Service Management Tools Needed

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Sensor Systems

Middleware Servers

Configuration Management

Acquisition
Processing
Monitoring
Viewers
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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
QUESTIONS?

NASA SBIR contracts are playing key roles in the creation of versatile research tools to enable development of a global-reach Earth observation system that can even analyze hurricanes. How can the SBIR program support your ideas?

NASA Photo by Bill Ingalls

NASA Photo by Tim Treadwell