Suborbital Telepresence and Over-the-Horizon Networking

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Motivation

- **Decision Support**
  - Situational Awareness *with enough time to do something about it*

- **Test & Measurement Activities**
  - Airborne instruments
  - Earth science, space exploration and aeronautics applications

- **Network-centric thinking**
  - Network-distributed operations
  - Network computing: sensor webs
  - Toward easy, affordable, useful networking to/from aircraft
Outline

• Where We Are
  – Earth Science Capabilities Demonstrations, Suborbital Telepresence Project
  – Recent accomplishments

• Next Steps
  – Upcoming Mission
  – Disruption-Tolerant Networking
**Objectives**

- Develop/demonstrate low-cost products and services for airborne science
  - Sensor web: *i.e.* Instrument interaction/C4I
  - Situational awareness, decision support
  - Global-Reach Realtime Mission Monitoring
- Necessary on future autonomous vehicles, but value in application to *all* platforms
- Onboard system focus: payload needs
  - Acquisition, integration, recording, processing, communications mgmt services
- Terrestrial system focus: operation needs
  - Data processing, fusion, distribution, display, playback services
Objective: Demonstrate Capabilities

Historic Flight of NOAA Instruments Operating on an Unmanned Aircraft

Global Monitoring Division - ESRL-GMD
This story entered on Sat, Oct, 2006 11:52:29 AM PST

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air scientific payload on an

occurred during October

ime National Park, California,

to flights over

e current flight was made

ation between NOAA, NASA,

is flight, instruments from the

ory measured temperature,

ce gases during the flight that

Fire Mission October 2006
Objective: Instrument Interaction

- UAV flying in national airspace
- Repaired *in situ* instrument in flight
- Data Viewed Live at 34th Advanced Global Atmospheric Gases Experiment Meeting
Objectives: Demonstrate Capabilities
Aug/Sep 2006: NASA African Monsoon Multidisciplinary Analysis

“Major step forward in our capabilities for doing real-time monitoring and direction of missions” – Dr. Ed Zipser
• Tropical meteorology students participated from Utah (8 Sep 06)
Tropical Composition, Cloud, and Climate Coupling Experiment (TC⁴)

- Team distributed across Western hemisphere
- Study chemical, physical, dynamic processes in upper troposphere and transition layer between troposphere and stratosphere.
- 3 aircraft in coordinated flights
  - Over and through storms
  - Under A-Train Satellites
- >60 in situ and remote observation instruments
  - Add radar and balloon observations
  - Add predicted observations (forecasts)
Data Sets for TC⁴ Real-time Monitoring

• Satellite Imagery
  – GOES-E, GOES-10 (vis, infrared, ~15 min update)
  – Satellite & instrument FOVs – current and predicted tracks
  – Satellite products (e.g., to support postflight activities)

• Model Output
  – GEOS-5 & WRF model outputs available

• Aircraft Instruments
  – Flight tracks (waypoint and real time tracks)
  – Dropsonde (time/locations and skew-T)
  – Aircraft Instruments: health/status, data, cmd/cntrl (case-by-case)
    (LASE, Dial, AMPR, MTS, SSFR, PT, CAPS…)

• Surface and Balloon Observations
  – Radar (NPOL, SMART)
  – Lightning (Vaisala long range, Costa Rica lightning, WWLLN)
  – TicoSonde
  – Other (NATIVE)

• Stop-action playback for review and analyses
TC-4 Notional Architecture

Data Acquisition
Intermediate Processing
Data Distribution

Satellite State
Instrument State
Predicted Observations
Etc

Google Earth
Browser, Matlab, ArcGIS, etc

Closest Server

Airborne (DC-8)
Terrestrial
An Application Integration View

You

Your application(s)

Web Browser
Google Earth
World WIND
Matlab
ArcGIS
IDL

"the network"

Aircraft State
Satellite State
Instrument State
Measured Observations
Predicted Observations
Misc

All necessary data sources
Heterogeneous distributed sources

Measured Observations
Aircraft State
Satellite State
Instrument State
Telepresence: Architectural Framework

Vehicle Systems
- Flight Executive

{L,M,H}

Vehicle Ops

Flight Management

{L,M,H}

Science Systems
- Airborne Data Sys.

Science Management

{L,M}

Suborbital

Vehicle Mgmt

Observation Mgmt

Ground
Where to next?

- Disruption Tolerant Networking (DTN) with aircraft
  - Classic Internet protocols (TCP-IP) designed for
    - “low bit error rate” environments
    - “low latency” environments
    - Symmetric link characteristics
    - End-to-end connectivity in quasi-static topologies
  - But Internet finally catching up with aerospace and test/measurement needs
    - Space Communications Protocol Standards (SCPS) Evolving for 15 years
    - Disruption Tolerant Networking R&D efforts expanding rapidly
      - IRTF: DTNRG.ORG
      - Significant DARPA DTN investment
      - Bundle Protocol (BP) Draft Specification v6 available Apr07
    - DTN BP is a store-and-forward overlay network
      - addresses general problem of managing end-to-end management of network transfer where end-to-end connectivity may not exist.
      - Scheduled, opportunistic, and predicted connectivity in dynamic topologies
  - DTN enables the vehicle payload to be its own autonomous Internet that cooperates with other vehicles and other ground networks as necessary
    - Long term: The network is a distributed autonomous intelligent system of systems
    - Near Term: better performance, more flexibility, extended line of sight, etc.
Disruption Tolerant Networks

- Advanced Experimental Systems Project:
  - Implement Multi-Link Disruption Tolerant Networking (DTN)

Suborbital Equivalent to Space Communication Architecture
Concluding Thought: Why Network Computing?

“…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!!!