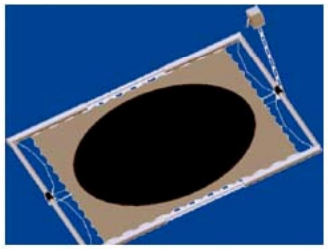
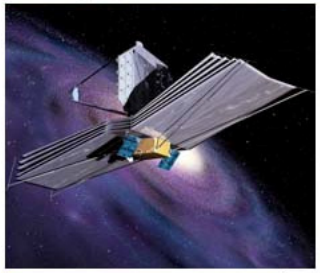
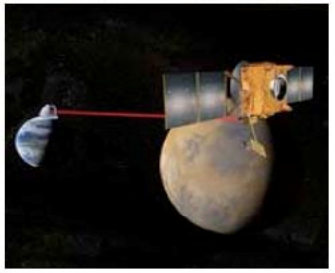
Jet Propulsion Laboratory
California Institute of Technology

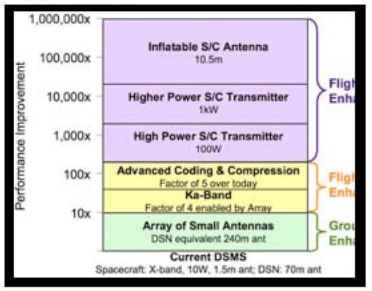
SpaceOps 2006

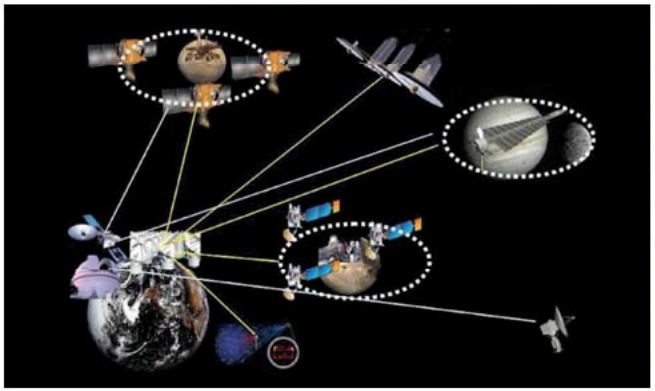
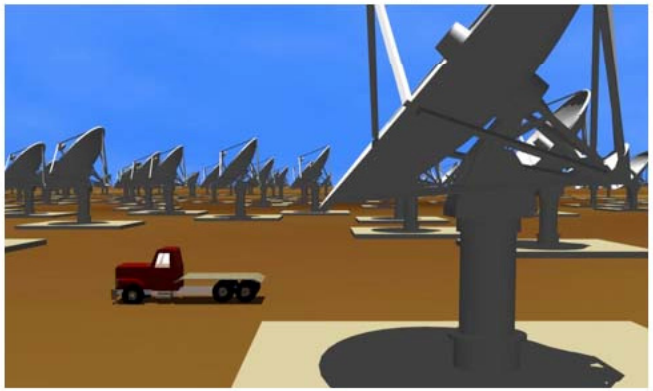
Asynchronous Message Service for Deep Space Mission Operations

Scott Burleigh






Asynchronous Message Service
Motivation

- CCSDS File Delivery Protocol (CFDP) helps standardize deep space mission ops, but not all mission information is in files:
  - Continuous telemetry.
  - Real-time commanding.
  - Inter-spacecraft coordination.
- As software grows in capability it tends to become more complex.
  - Increasing complexity tends to increase risk and therefore cost.
  - Modular design can reduce software complexity, but resulting growth in inter-module message exchange increases system complexity.
  - Standardizing inter-module messaging can reduce system complexity.
- "Publish-subscribe" asynchronous message exchange can simplify system operations and improve both message delivery latency and bandwidth efficiency, but there is no broadly used open international standard for it.
- So CCSDS has undertaken development of such a standard: CCSDS Asynchronous Message Service (AMS).

Asynchronous Message Service
Overview of AMS

- **Core "message bus" model: each application software node subscribes to (and consumes) the information it needs, and publishes the information it produces, without knowing which other modules are currently running.**
  - **Explicit awareness of other node is provided as well, as needed.**
  - **Private message transmission to specific nodes, including replies to published messages, is supported as needed.**
  - **Synchronous (client/server) communication is supported as needed.**
- **Purpose: reduce cost and risk by enabling message exchange that is…**
  - **Simple to use**
  - **Highly automated**
  - **Flexible**
  - **Robust**
  - **Scalable**
  - **Efficient**

Asynchronous Message Service
Abstract "UT layer"

- Like CFDP, AMS is designed to run over transport systems that provide the necessary connectivity and quality of service.
  - Buses (e.g., 1553)
  - Message queues
  - Internet paths
  - CCSDS-conformant links
- Advantages of UT layer abstraction in deep space operations:
  - Simple migration of software between flight and ground
  - Scaling from on-board to interplanetary environments
- Advantages in ground operations:
  - Stable installed base of standard terrestrial network protocols
  - Simple integration with existing systems
- Advantages in on-board operations:
  - Leverage from real-time QOS features of on-board infrastructure

Asynchronous Message Service
Quality of Service

- **AMS itself doesn't implement QOS measures; it relies on the measures provided by UT-layer protocols.**
  - **Makes AMS itself smaller.**
  - **Enables use of AMS in an unlimited variety of environments.**
- **But AMS is still sensitive to QOS requested by the application:**
  - **Application can specify transmission *mode* to AMS, causing AMS to select an underlying transport protocol with the desired characteristics.**
    - **Assured or best-effort message delivery.**
    - **Delivery in arrival order or preservation of transmission order in delivery order.**
  - **Application can specify *priority* and *flow label* to AMS. These parameters are opaque to AMS; AMS simply passes their values through to the selected underlying transport protocol.**

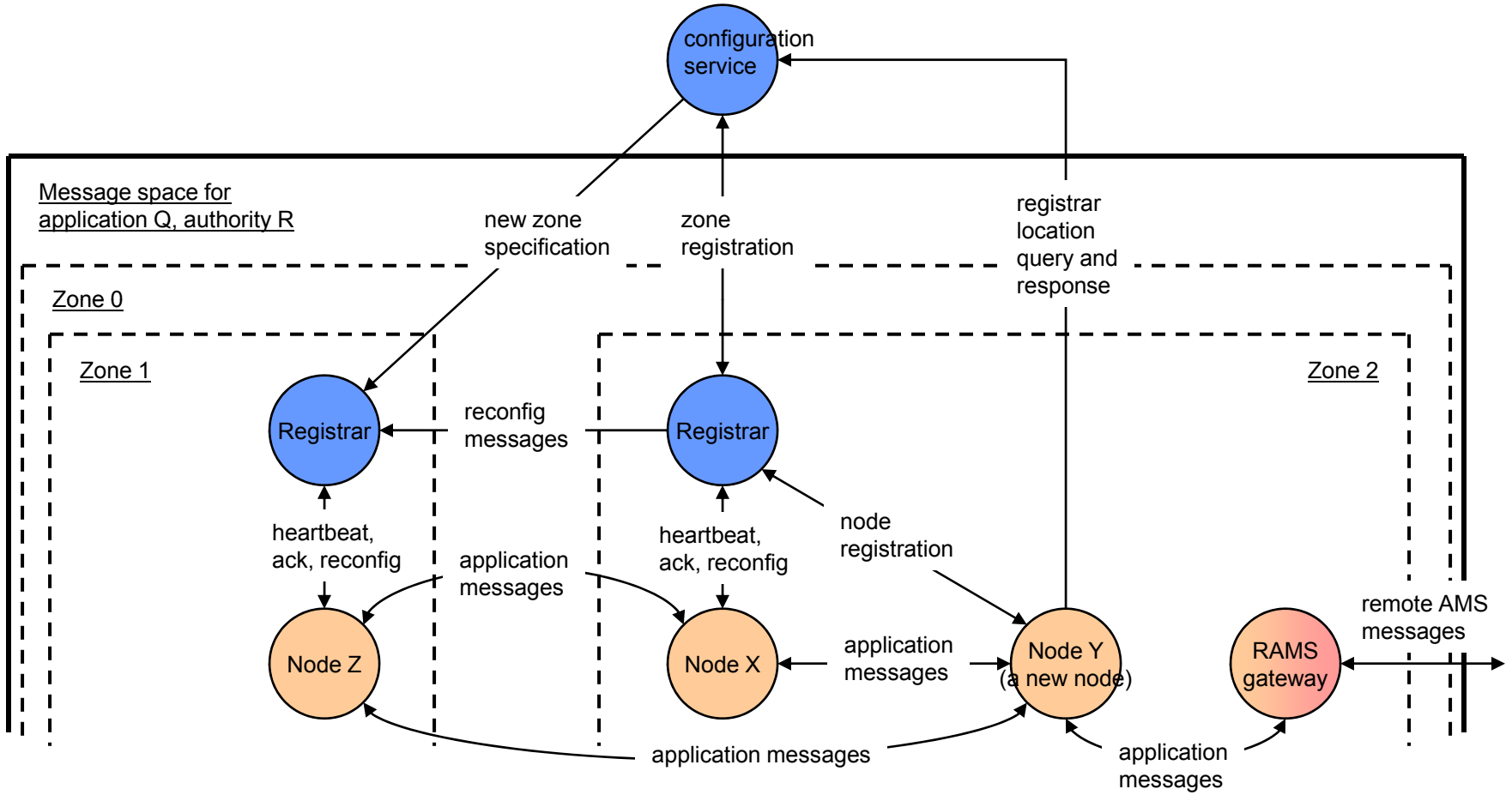
Asynchronous Message Service
Constraining transmissions

- **Transmission constraints can be specified in subscriptions (selecting publishers) and in announcements (selecting recipients).**
  - **Constrain to all – and only – nodes registered in a specified zone or in any zone that's wholly contained within the specified zone.**
  - **Constrain to all – and only – nodes declared at registration to be performing a specified *role* in the application.**
  - **Constrain to all – and only – nodes operating within a specified continuum.**
- **This fine-grained control over message publication enables a balance to be struck between latency and bandwidth utilization.**
  - **Information is pushed rather than pulled, so there is no query/response round trip delay.**
  - **But information need never be pushed to nodes that aren't interested in it.**

Asynchronous Message Service
Additional features

- **Security**
  - **Access control**
  - **Authentication**
  - **Encryption**
- **Fault tolerance**
  - **Preventive maintenance**
  - **Inference of remote node failures**
  - **Failover**
  - **Autonomous recovery**
- **“Announcement” of data to anonymous nodes**
- ***Remote AMS* (RAMS) aggregates message publication to minimize bandwidth consumption on constrained links.**
  - **Designed to enable dynamic publish/subscribe functionality over interplanetary distances**

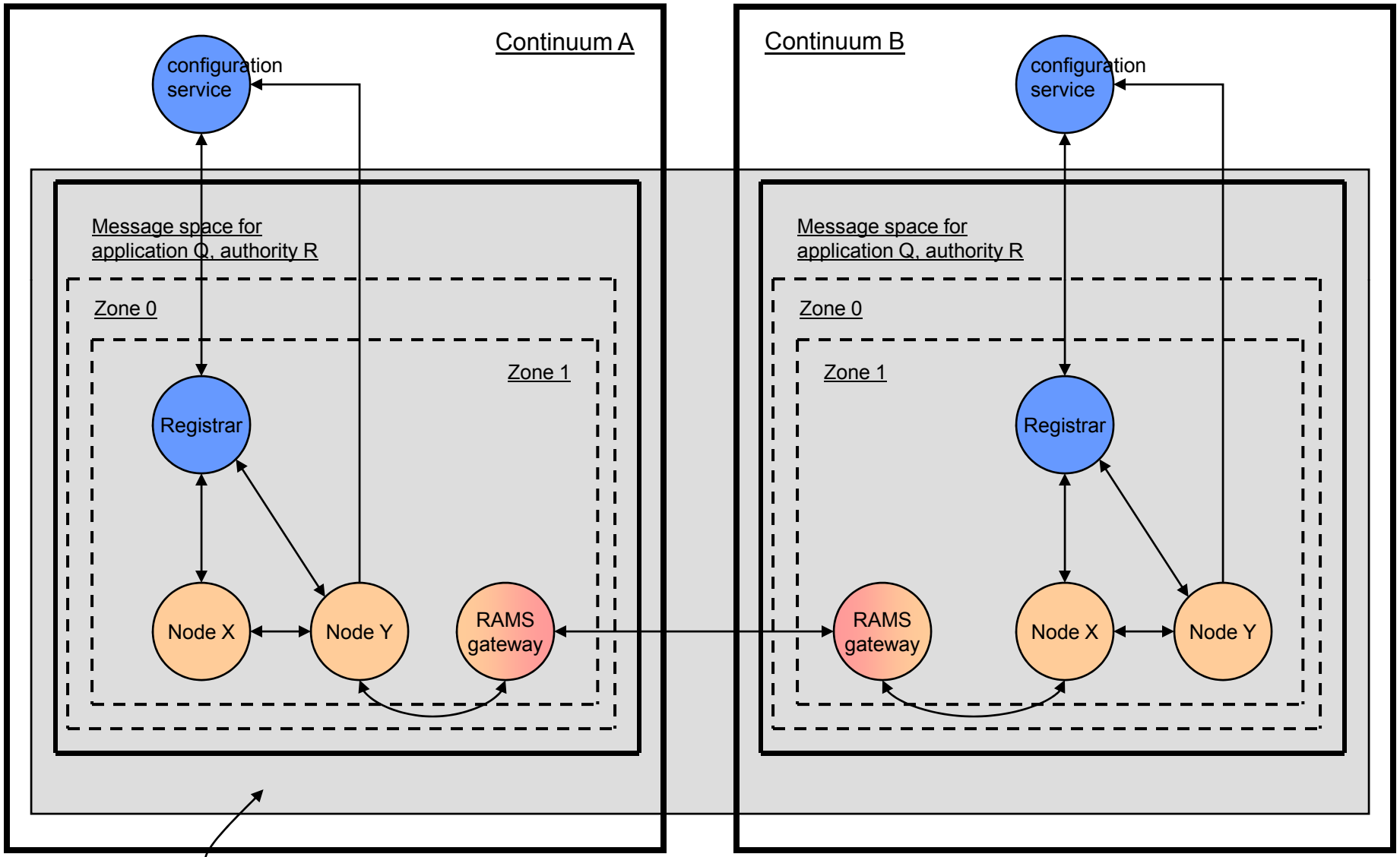
Asynchronous Message Service Operations: a single AMS continuum



Asynchronous Message Service
The AMS Protocol Suite

- **Meta-AMS**
  - **Discovery, self-configuration (including subscriptions and unsubscriptions), fault detection, failover, recovery.**
  - **Messages are exchanged between nodes and configuration servers, between nodes and registrars, between configuration servers, between registrars, and between registrars and configuration servers.**
- **AMS**
  - **Application data transmission; queries, replies, announcements.**
  - **Messages are exchanged between nodes (including RAMS gateways, which function as AMS nodes).**
- **Remote AMS**
  - **Assertions and cancellations of "petitions"; aggregated application data transmission.**
  - **Messages are exchanged between RAMS gateways.**

Asynchronous Message Service Operations: a multi-continuum "venture"



Concatenated application instance ("venture") for application Q, authority R.

Asynchronous Message Service
Performance of Prototype Implementation

Number of messages sent	*Size of each message (bytes)*	*Messages exchanged per second*	*Data rate (Megabits/sec)*
10,000	20,000	5,337	814
100,000	2,000	25,739	393
1 million	200	107,910	165
10 million	20	154,335	23

Highly preliminary performance measurements, from JPL's Protocol Test Laboratory. Message exchange between a single publisher and a single subscriber on a Gigabit Ethernet. Each node was hosted on a dual-core 3Ghz Pentium-4 running Fedora Core 3. (Don't expect this kind of performance in normal operations!)

Asynchronous Message Service
Conclusion

- **AMS is in early stages of standardization.**
  - **CCSDS "white book" (Proposed Standard) has been published.**
  - **A single implementation has been developed and is being tested.**
- **No major obstacles encountered so far.**
  - **Protocol has changed since original concept paper, but not radically.**
  - **Design concepts seem to be sound.**
- **AMS capabilities seem to be broadly applicable.**
  - **On-board, proximity, and deep-space communications for spacecraft.**
  - **Suitable underlying messaging protocol for proposed CCSDS Spacecraft Monitor and Control protocols.**
  - **Terrestrial applications designed for operation over a message bus.**
- **AMS Working Group within CCSDS is on schedule, so far.**