A NASA SCaN SysML Profile Adaptation

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Agenda

- What is SCaN?
- Program Systems Engineering
- Integrated Network Architecture
- INA Trade Study
- MBSE in SCaN
- Lessons Learned
- Conclusions
- Questions

What is SCaN?

- Space Communication and Navigation
  - Program that is responsible for all NASA space communication and navigation support infrastructure
- One critical element of SCaN is Program Systems Engineering (PSE)

Program System Engineering
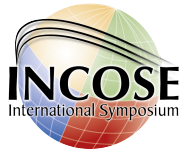
- Conducts trade studies to analyze potential improvements to the network(s)
  - Development of analysis tools (Link budget, coverage, loading, etc)
  - TDRS Relay study
  - Service Planning
    - Network Integration Management Office (NIMO)
    - DSN Commitment Office (DCO)
    - "Combined" as Mission Commitment Office (MCO)
  - Integrated Network Architecture

Integrated Network Architecture
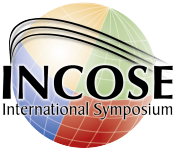
- Integration of NASA's three, independent space communications networks
  - Currently three separate entities
    - Some overlap between NEN and SN
  - DSE, NEE, EBRE (formerly DSN, NEN, SN)

Near Earth Network – Near Earth Element (NEN – NEE)
Deep Space Network – Deep Space Element (DSN – DSE)
Space Network – Earth-Based Relay Element (SN – EBRE)

"Should-Be" Architecture in 2018 Era
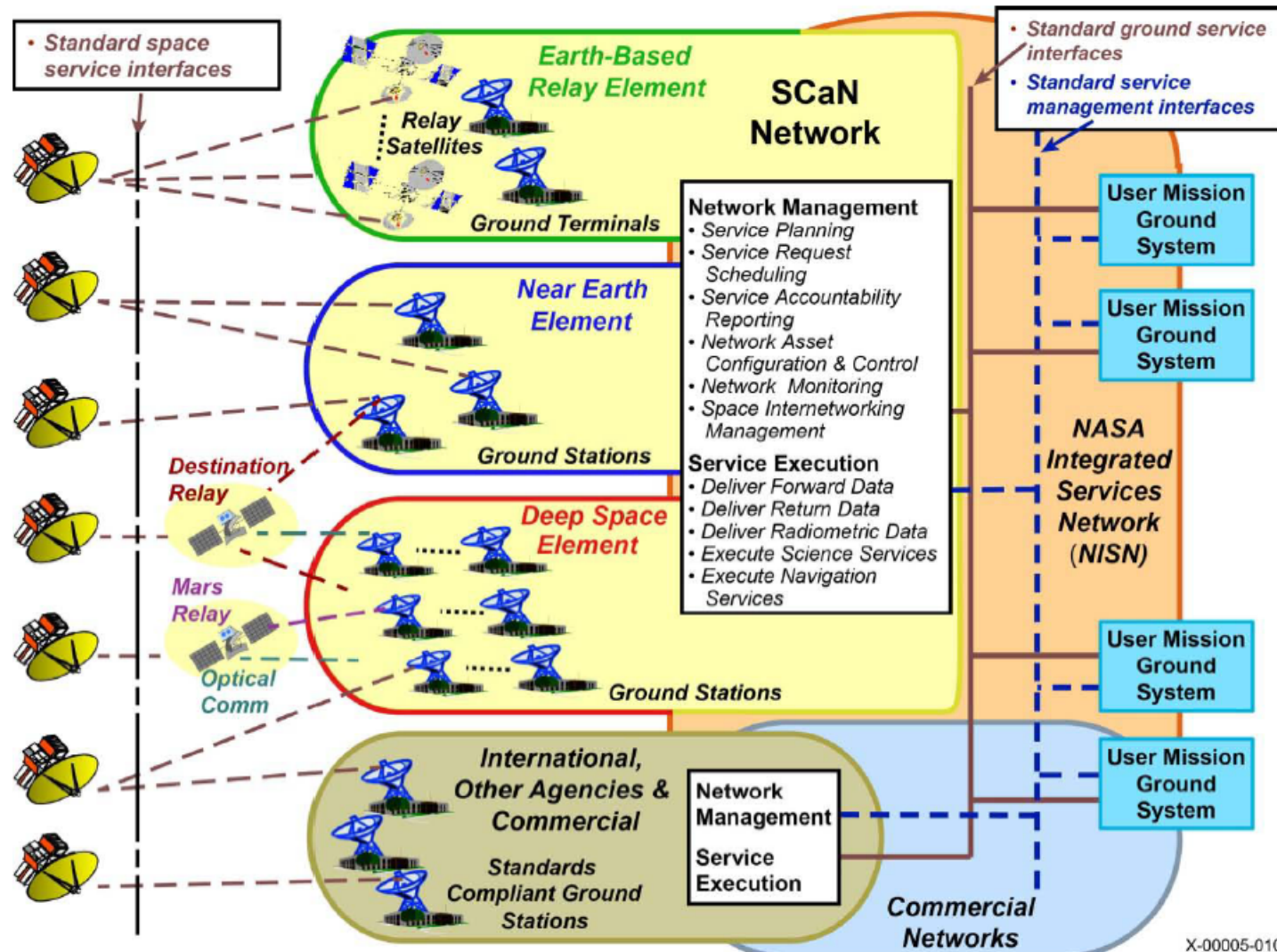
Integrated Network Functions

Mission Operations System

Integrated Network

Spacecraft

Mission Operations

Service Management
- Service Planning
- Service Request Scheduling
- Service Accountability Reporting

Flight Events Execution

Earth-Based Assets

Service Execution
- Forward Data Delivery
- Return Data Delivery
- Radiometric Data Delivery
- Position & Timing
- Instances of other service types

Network Control
- Network Scheduling
- Network Asset Configuration & Control
- Network Asset Monitoring
- Space Internetworking Management

Relay Assets

Service Execution
- Forward Data Delivery
- Return Data Delivery
- Radiometric Data Delivery
- Position & Timing

Service Management + Network Control = Network Management

WT-7

INA Trade Study

- Multi-center team
  - GRC, JPL, GSFC
- Multiple cycles building on each other, narrowing scope
  - INM > INC > ISM > SP > SRS > NCC > IF…
- Team identifies several options as solutions
- Final cycle recommendation review
  - Best value architecture selection, cost breakdown based on WBS, FOM scoring, risk analysis

MBSE in INA Trade Study

- Independent evaluation of tools conducted at JPL and GRC
  - Teamwork repository hosted at GRC
- SysML selected for modeling
  - DoDAF framework examined, but not used
  - BDD, IBD, Activity, Sequence, Use case
  - Two team training courses, mostly self taught

MBSE TS teams

- TS team divided
  - Operations team
    - Evaluate POD* system processes
    - Evaluate processes based on integrated options
    - Develop activity and sequence diagrams based on research
  - Data systems team
    - Evaluate POD* data systems
    - Evaluate data systems based on integrated options
    - Develop BDD and IBD diagrams based on the options
  - Both teams
    - Define areas in NEE and DSE for SGSS adaptation

*SGSS considered POD for EBRE

Example diagrams

MagicDraw UML, 1–1 INC Trade Study Designs ver_2.3.mdzip Integrated Mission Scheduling Model Apr 26, 2012 4:29:31 PM
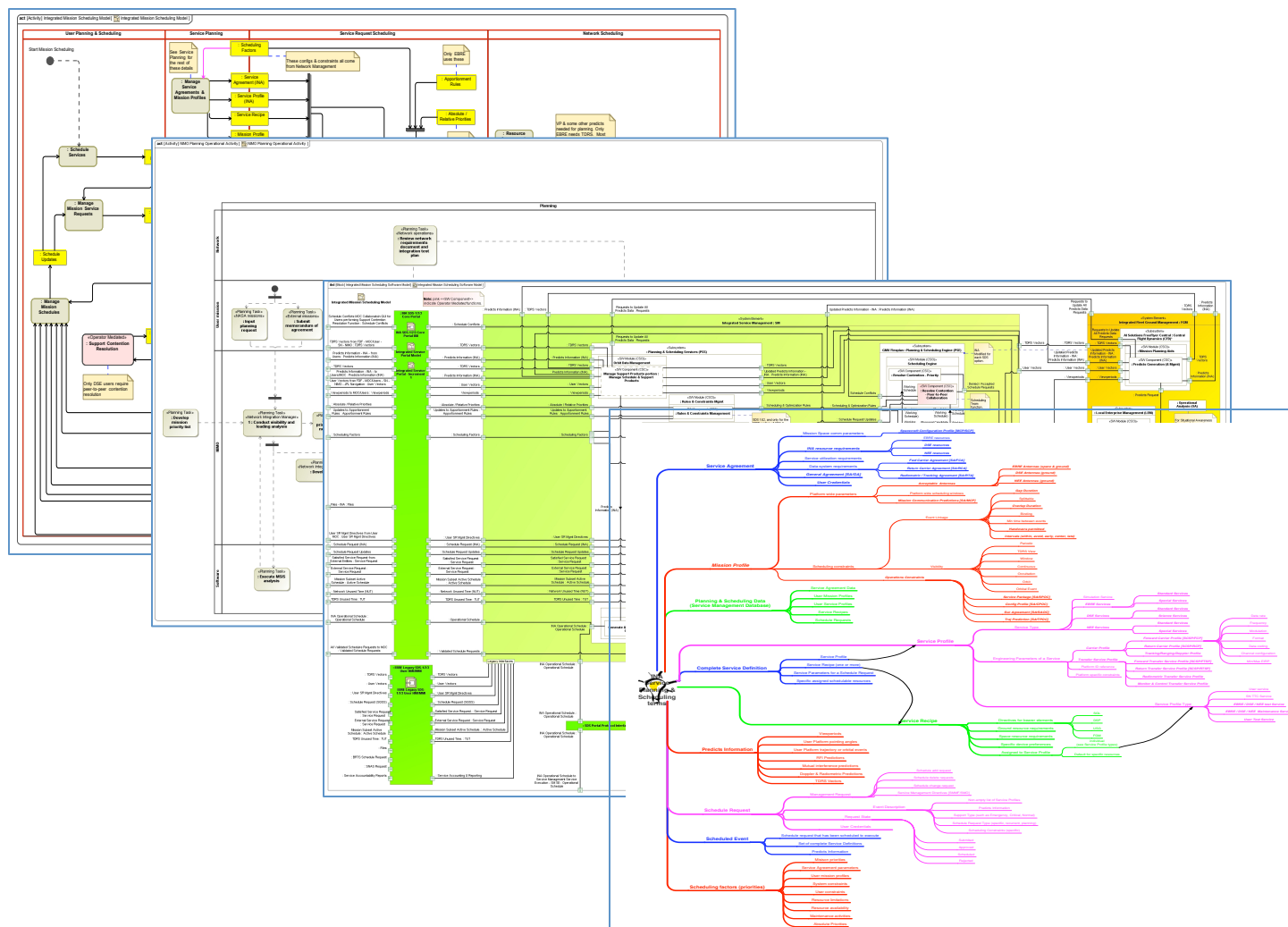
MBSE methodology

- Model navigation
- Model hierarchy
- Element library
- Stereotyping
- Timestamping
- Swimlanes (time and role)

Lessons Learned

- Separate modeling teams
  - Geographically diverse
  - "Too many cooks"

- Problem
  - Inconsistency in model
  - Non-linkage between data and ops

- Solution
  - Regular (weekly) modeling tag ups to discusses issues and current work

Lessons Learned

- Changing methodology
  - Fine tuning the model
    - Refining stereotypes
    - Timestamp scheme
    - Showing duration

- Issue
  - Incongruent models between cycles

- Solution
  - Rework of "completed" models

Lessons Learned

- Presentation format
  - Powerpoint widely used
  - Models are enormous

- Issue
  - Unreadable models when formatted to ppt

- Solution
  - html browseable file (too large)
  - Large display for image files (one at a time)
  - Large scale, printed documents

Lessons Learned

- New team members
  - "Coming up to speed"
    - SMEs have 30+ years experience
  - TS always moving forward
- Issue
  - New team members unable to catch up to speed fast enough to be productive
- Solution
  - MBSE
    - Single model equivalent to 100 page document

Conclusions

- Learning process
  - Track lessons learned
  - Use to iterate and revise process
- Model used as basis for future work
  - More specific studies spin off the main cycles
- Dynamic team
  - MBSE allows for transfer of personnel

Conclusions

- PSE has invested in MBSE
  - Started in Trade Study; now spread to ADD, ConOps, SRD, Tools
  - De facto standard for diagram creation
  - Single model growth
    - Cycles are added to the existing model
    - Reuse of work, linkage through several levels
    - ConOps, ADD, SRD teams reusing data elements

Thank you

Questions ?

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Backup

Integrated Scheduling Operations Process Flow

Forecast time period can be years ahead of time

«NA Functions» Service Planning		«NA Function» Service Request Scheduling		«NA Function» Network Scheduling

User mission

«Planning Task» : Input User mission service planning request

«Scheduling Task» : Input User mission scheduling request

«Scheduling Task» : Peer-to-peer negotiations (optional)

«Scheduling Task» : Release apportionment time

«Scheduling Task» : Input User mission scheduling request

Commercial and Partner

«Scheduling Task» «Commercial Asset» : Send request accepts

Planning Office

«Scheduling Task» : Input planning documents

Network

«Scheduling Task» : Develop service agreement

«Scheduling Task» : Develop service profile

«Scheduling Task» : Develop service recipe

«Scheduling Task» : Develop user mission profile

«Scheduling Task» : Load control table

Scheduling Team

«Planning Task» : Input long-term network asset availability

Compatibility testing

«Scheduling Task» : Input maintenance, sustainment, and test schedule request

«Scheduling Task» : Initialize new scheduling period

Deconflicted schedule acceptable? — No — «Scheduling Task» : Manual schedule adjustment

Yes

«Scheduling Task» : Input maintenance, sustainment, and test schedule request

Scheduling Data System

NIMO develops a "Loading Analysis" which is a type of schedule, but not called a schedule. DOO develops an "Integrated Master Schedule". Neither currently uses the term "Forecast schedule"

«Planning Task» : Develop forecast schedule

«Scheduling Task» : Input asset/network resource parameters

«Scheduling Task» : Load operational database

«Scheduling Task» : Ouput planning and scheduling operational database

«Scheduling Task» : Accept, verify and manage requests

«Scheduling Task» : Develop working schedule

«Scheduling Task» : Identify conflicts

«Scheduling Task» : Resolve conflicts / optimize

No — Schedule meets optimization requirements generated? — Yes

«Scheduling Task» : Promote final working schedule to active schedule

«Scheduling Task» : Accept, verify and manage requests

«Scheduling Task» : Publish Network Unused Time (NUT)

Schedule request received? — Yes — «Scheduling Task» : Revise active schedule

No

«Scheduling Task» : Promote final active schedule to operational schedule

«Scheduling Task» : Distribute operational schedule to HCO

«Scheduling Task» : Send commercial requests

«Scheduling Task» : Publish schedule to users

21

Integrated Scheduling – Functional Model

INCOSE International Symposium

| User Planning & Scheduling | Service Planning | Service Request Scheduling | Network Scheduling |

Start Mission Scheduling

: Scheduling Factors

See Service Planning for the rest of these details

These configs & constraints all come from Network Management

Only EBRE uses these

: Manage Service Agreements & Mission Profiles

: Service Agreement (INA)

: Service Profile (INA)

: Service Recipe

: Mission Profile (INA)

: Apportionment Rules

: Absolute / Relative Priorities

: Resource Assessment

VP & some other predicts needed for planning. Only EBRE needs TDRS. Most EBRE & NEE predicts are generated later in the process. DSE generates full set of Support Products 3 days ahead of time.

: Schedule Services

: Schedule Request (INA)

: Accept & Verify Schedule Requests

: Rules & Constraints Management

EBRE & NEE use these, DSE does not

: Resource Availability

: Predicts Generation (& Mgmt)

: Manage Mission Service Requests

: User SR Mgmt Directives

: User SR Mgmt Directives

: Validated Schedule Requests

: Scheduling & Optimization Rules

: Network Rules & Constraints

Predicts Info from Users : Predicts Information (INA)

: TDRS Vectors

: User Vectors

: Manage Schedule Requests

: Develop Service Request Schedule

: User Vectors

: Predicts Request

: Viewperiods

: Schedule Updates

All Valid Schedule Requests : Validated Schedule Requests

: TDRS Vectors

Updated Predicts Information (INA) : Predicts Information (INA)

External Service Request : Service Request

: Request External Services

: Manage Mission Schedules

Proposed Working Schedule : Working Schedule

Candidate Working Schedule : Working Schedule

Satisfied Service Request : Service Request

: Predicts Information (INA)

DSE uses peer-to-peer, collaborative, multi-user contention resolution

Requests to Update All Predicts Data : Requests

«Operator Mediated» : Support Contention Resolution

: Schedule Request Updates

: Schedule Request Updates

«Operator Mediated» : Resolve Contention - Peer-to-Peer Collaboration

: Resolve Contention - Priority

Conflict Free Active Schedule : Active Schedule

: Manage Schedule & Support Products

External & Internally Updated User Vectors : User Vectors

: Schedule Conflicts

Only DSE users require peer-to-peer contention resolution

Part of the interactive process between the network schedulers & the users

DSE & NEE provide Network Unused Time (NUT) report. EBRE only provides TUT, a heavily filtered report.

: Denied / Accepted Schedule Requests

EBRE & NEE use priorities

EBRE & NEEE Master Sched only 7 days, DSE is 8-16 weeks.

: Viewperiods

: Predicts Information (INA)

: Network Unused Time (NUT)

: Generate & Filter Reports

: Active Schedule

TDRS Unused Time : TUT

: TDRS Vectors

Committed "Event" Scheduled

Mission Subset Active Schedule : Active Schedule

: Generate & Distribute Operational Schedule

: Operational Schedule

Not available to EBRE users

Active Schedule updated every 2 hours, or more frequently if needed (depends on network).. Covers 6 hours of operation for EBRE, 7 days for DSE. Not available to EBRE users.

22