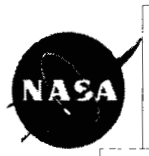

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Cost Reductions From Multi-Mission Sequencing Software

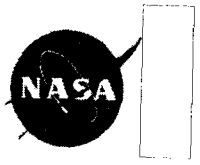
L. Needels

Jet Propulsion Laboratory

California Institute of Technology

Agenda

- Introduction to SEQ
- Multi-mission Architecture Cost Savings
- Automated Sequence Processor Cost Savings
- Summary

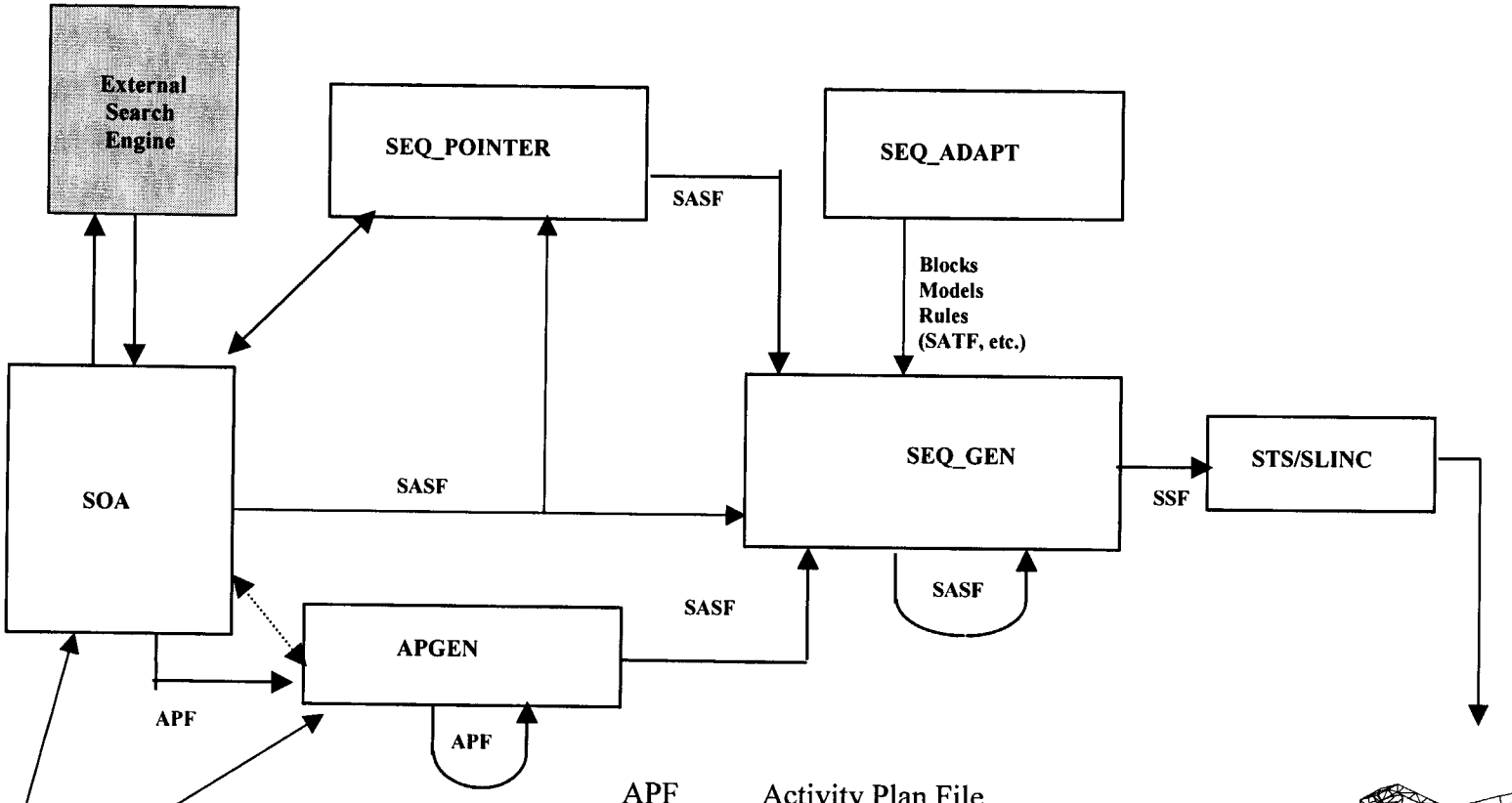


Introduction to SEQ

Sequencing Process

- SEQ refers to a component of the Advanced Multi-Mission Operations System (AMMOS), which is part of the Interplanetary Network Directorate (IND) at JPL.
- SEQ consists of software that facilitates
  - Planning and creation of science and engineering activities
  - Command syntax checking
  - Sequence integration
  - Mission and Flight Rule Checking
  - Command translation
  - Several other aspects of preparing for the uplink process such as the software that assists users in looking at expect events on the spacecraft and software used to schedule the Deep Space Network antennas.

SEQ Software Flow



APF	Activity Plan File
PEF	Predicted Events File
SASF	Spacecraft Activity Sequence File
SATF	Spacecraft Activity Type File
PEF	Spacecraft Sequence File
SSF	Spacecraft Sequence File

SEQ - Science Planning Tools

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- SEQ offers two tools that can be used for science planning.
  - Science Opportunity Analyzer (SOA)
  - Planetary Observation Instrument Targeting and Encounter Reconnaissance (POINTER)

SEQ - Science Planning Tools

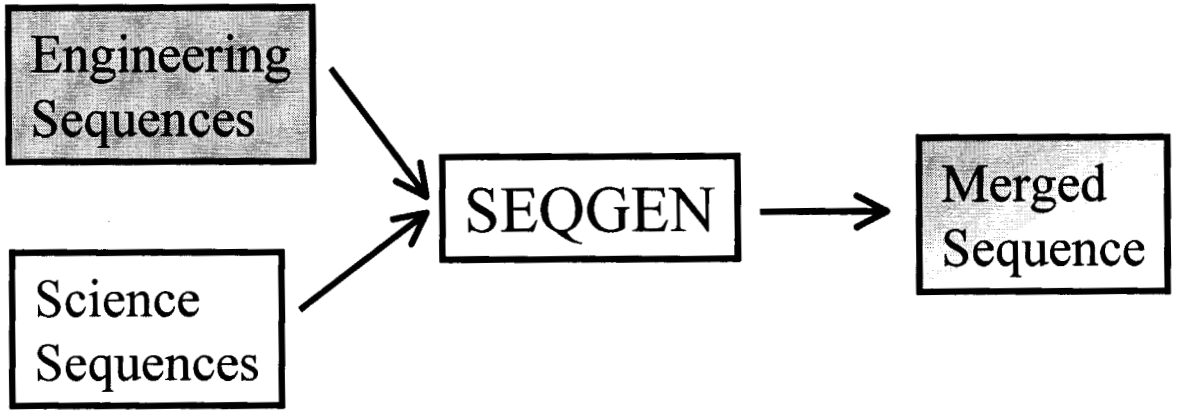
- SOA
  - An observation planning tool that works at the activity level
  - Interfaces with external search engines that will locate times of interest (flybys, bow-shocks, occultations, periapsis, etc.)
  - Design of a specific observation (Continuous Scan, Roll Scan, Start/Stop Mosaic, Stare, etc.)
  - Constraint Checking (activity duration, distance, exclusion zones, hardware limits, etc.)
- POINTER
  - Works at the command level
  - More detailed calculations
  - More detailed constraint checking

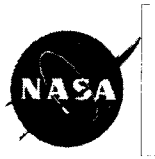
SEQ - Engineering Planning Tool

- Activity Plan Generator (APGEN) is used to plan engineering activities
  - Activities (DSN contacts, science activities, general engineering activities, etc.) are monitored against resource constraints (solid state recorder space, propellant, battery state of charge, etc.).
  - Scheduling of activities can also be completed.

SEQ - SeqGen

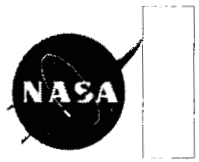
- SeqGen (Sequence Generation) is the work horse of SEQ. SeqGen is used to
  - Generate sequences.
  - Integrate sequences (which may have been generated by SOA, POINTER, APGEN, SeqGen or other tools).
  - Verify command syntax.
  - Verify Flight and Mission Rules that have been coded in SeqGen.





SEQ- Sequence Verification

- SeqGen does some of the sequence verification.
  - Command syntax
  - Mission and Flight rules
  - Some types of parameter checking
- Spacecraft Language Interpreter and Collector (SLINC) packetizes and translates the commands into binary format.
  - Out of Range checking for all types of parameters is done.



Multi-mission Architecture Cost Savings

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Change in Sequence Architecture

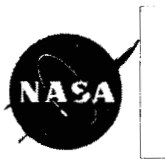
- Until the early 1990s, each spacecraft developed its own individual sequencing system/programs. Sequencing systems are quite expensive to develop
- In an effort to reduce cost and development time, a "Multi-Mission" Sequencing architecture was developed which promoted reuse of sequencing system components.

Multi-Mission Sequence Architecture

- CORE software consists of a capability. E.g. the ability to track user defined states.
- ADAPTATION software is the set of project specific files that use the core software. E.g. a specific flight rule implementation.

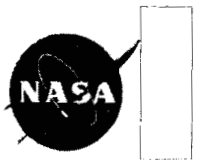
Multi-Mission Sequence Architecture Cost Savings

- Capability is implemented and verified only once.
- Team familiarity.
- Teams (E.g. Flight Software or Assembly, Test, and Launch Operations) are ready to hit the ground running because much of the capability is already available.
- Inherently more reliable.



Multi-Mission Sequence Architecture Cost Savings

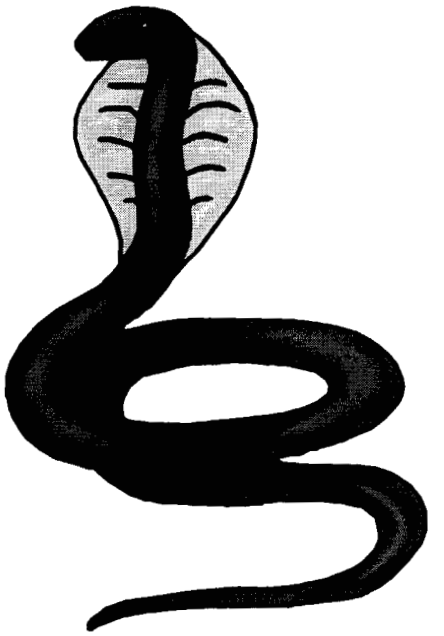
- Cost savings not always immediately apparent to projects.
- Return On Investment showed that mission specific adaptation of multi-mission tools cost ~15% of mission specific costs.
- Cost Savings = $Cost_{No\_Reuse} - (Cost_{Adaptation} + CostProject\ Specific\ Changes)$



Automated Sequence Processor Cost Savings

Automated Sequence Processor Cost Savings

- ASP is a collection of scripts that were developed to automate the sequence generation process during Aerobraking phase of MGS mission.



Automated Sequence Processor Cost Savings

- Ops team size significantly smaller.
- Remote teams can stay remote.
- Automatic verification of products.
- Some commanding can be done completely autonomously (24x7) with no Ops staff on shift.

Automated Sequence Processor Cost Savings

- Processing & verification of a command load
  - used to take about 2 hours
  - now it takes about 5 minutes
  - Return on Investment showed that ~$250 K had been spent on ASP development and upgrade. Savings from time not spent by sequence teams was ~$3.4 M. (There is an additional ~$40 K/year spent for ASP maintenance.)

Summary

- Two ways to save money in mission operations.
  - Software reuse.
  - Process automation.