Integrated Planning and Scheduling for NASA's Deep Space Network – from Forecasting to Real-time

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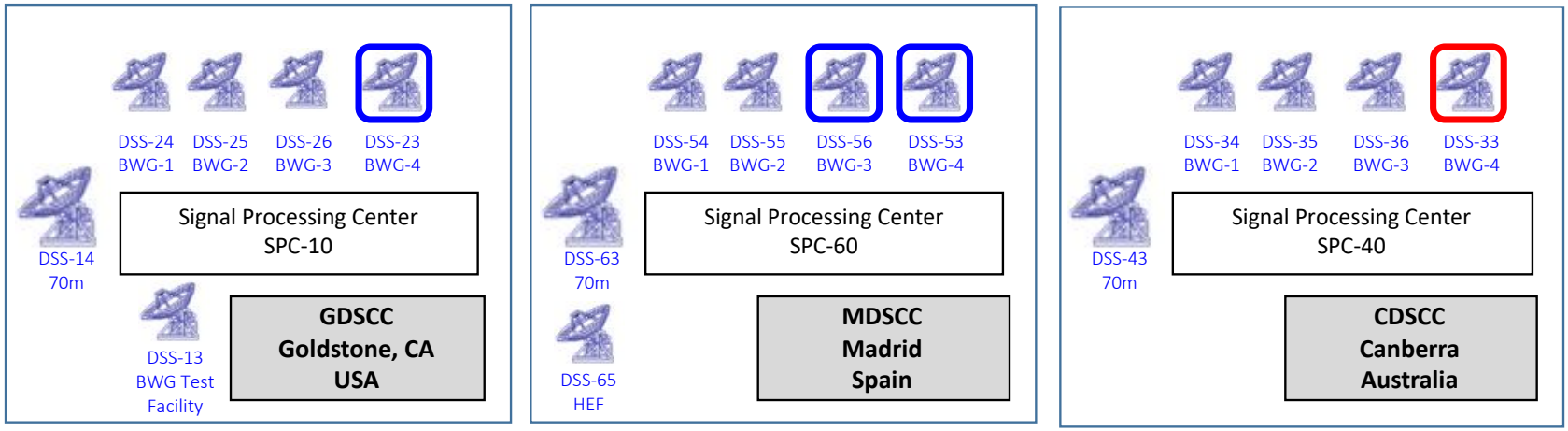
Overview

- Deep Space Network (DSN)
- Planning and Scheduling for the DSN
- Loading Analysis and Planning Software (LAPS)
  - context
  - interfaces
  - functions
- Deployment
- Conclusions
  - status and plans

Deep Space Network (DSN)

- Network of 34- and 70-meter antennas in California, Madrid, and Canberra
  - All deep space missions use DSN for communications and navigation
- DSN is currently oversubscribed
  - 35 missions / science users dependent on DSN services
  - Limited network assets
  - Multi-use equipment (antenna testing / maintenance, calibration, science users)
- Small satellites represent new customer base for network

Deep Space Network Complexes and Antennas



New Antennas Not Completed Yet

80-kW BWG

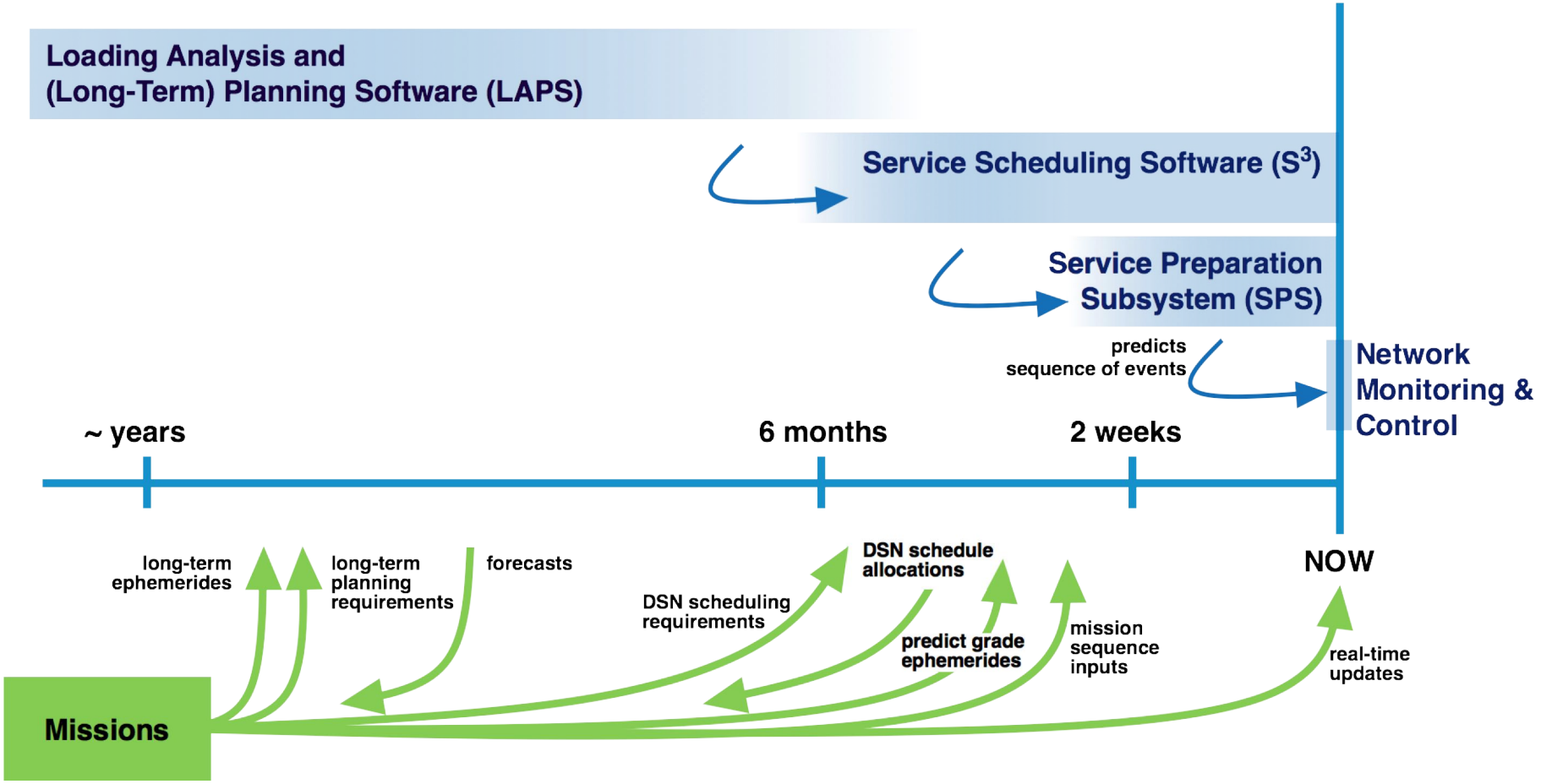
20-kW BWG

LAPS Purpose and Scope

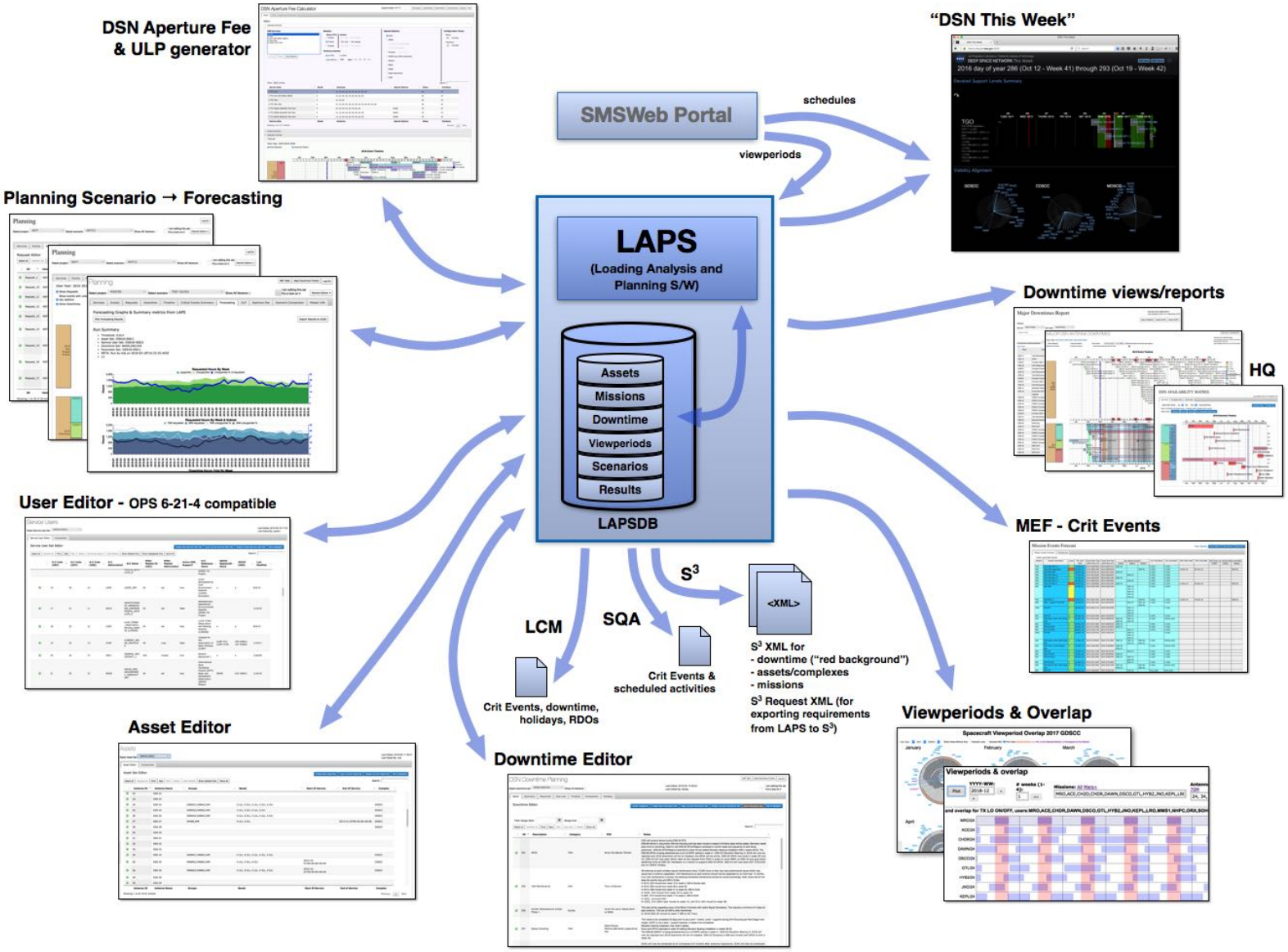
The **DSN Loading and Planning Software (LAPS)** shall:

1. Generate loading analyses and forecasts to support DSN planning and scheduling, including baseline and “what-if” scenarios
2. Manage associated data required for (1), including versioning and access control
3. Provide data and reports to users in support of (1) and (2)

Planning and Scheduling Information Flow

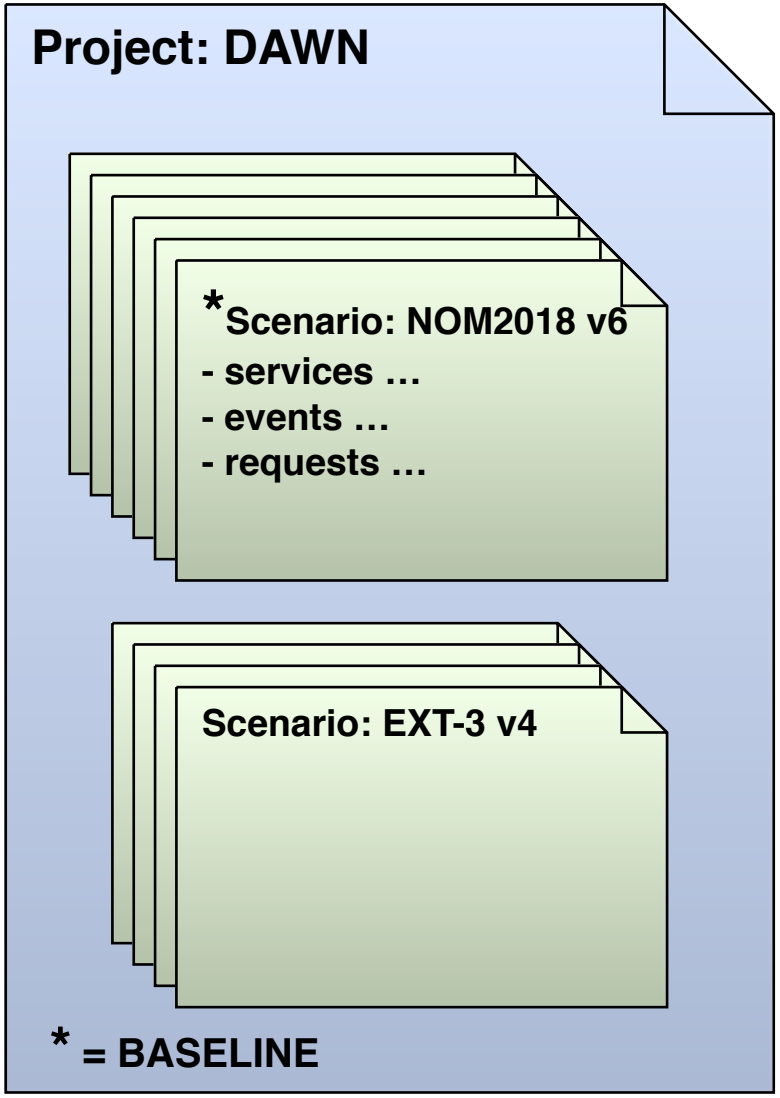


LAPS — Context and Features



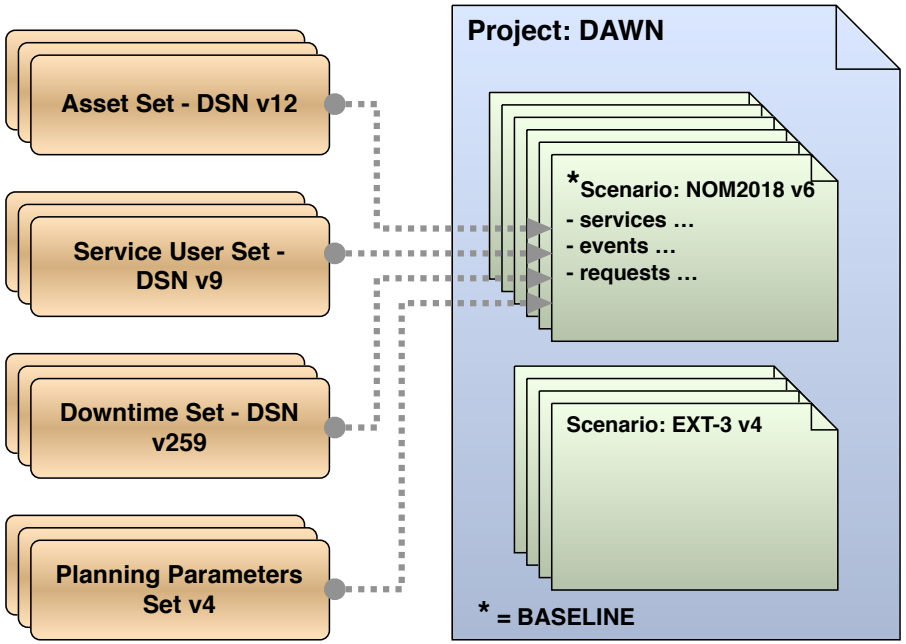
LAPS Data Model

- LAPS planning data is organized into **Projects**, each of which contains one or more **Scenarios**
  - Scenarios are versioned (0,1,2,…)
  - Each project has a specific baseline version
  - Access controls are at the Project level are (read/write/run)



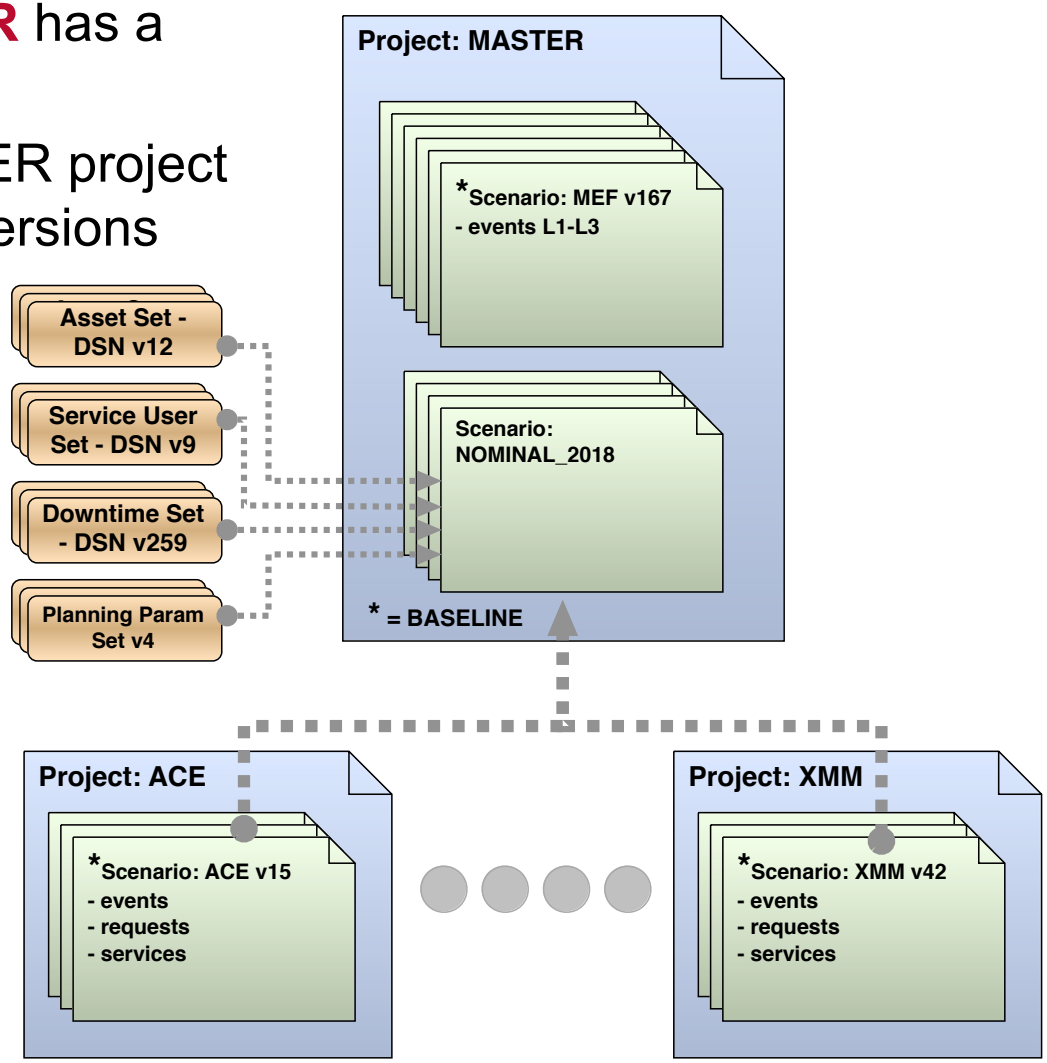
LAPS Data Model – Scenarios

- Scenarios **contain**:
  - Planning requests – e.g. “3x 8-hour tracks/week on X-band antenna during Cruise”, “1 N-S DDOR daily during Approach”
  - Service requirements – TTC, VLBI, Beacon, array, DDOR, …
  - Events – time ranges of interest to missions (e.g. Cruise, …)
- Scenarios **refer** to:
  - Asset sets and time-phased asset capabilities
  - Service users sets for S/C info (including aliases)
  - Downtime for asset availability times
  - Planning parameters for miscellaneous additional info

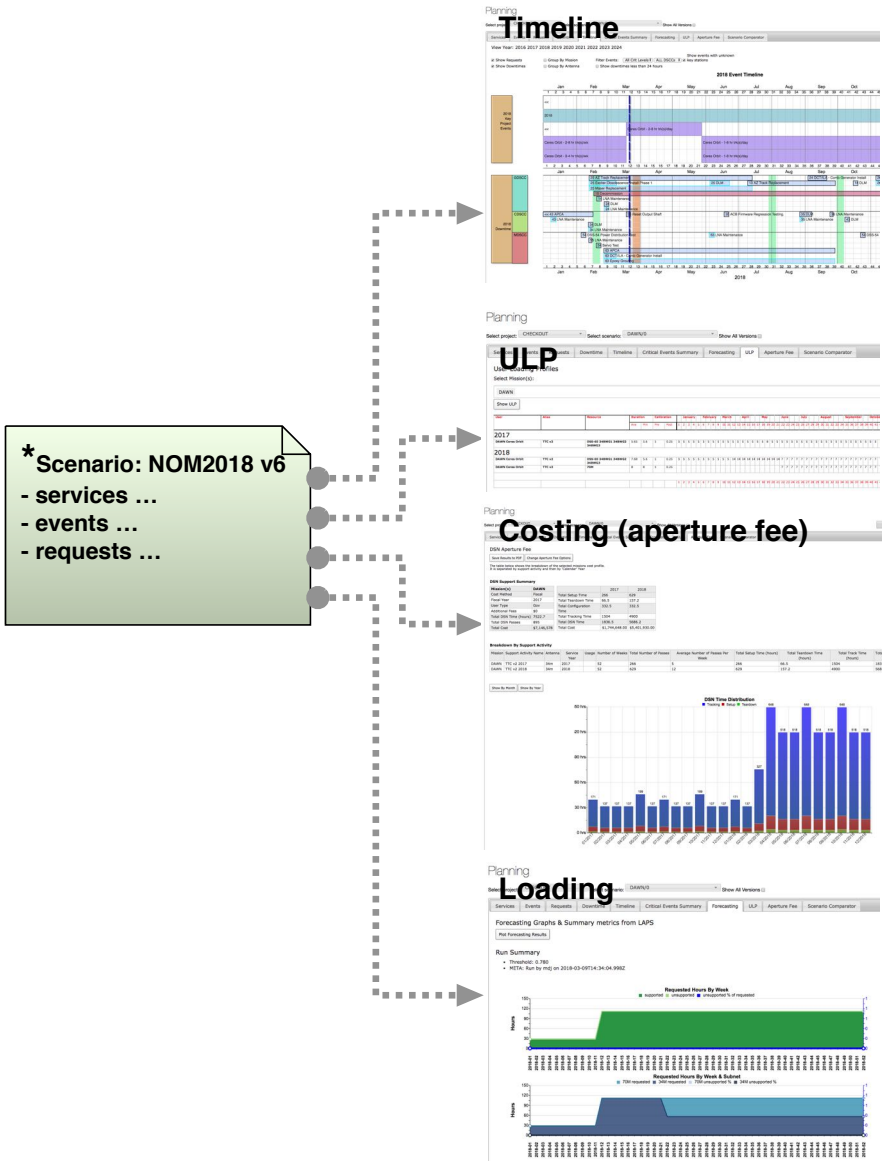


LAPS Data Model – MASTER Project

- One project called **MASTER** has a special role:
  - Scenarios in the MASTER project can refer to scenarios/versions in other projects – they will be included in forecast runs
  - The baseline Scenario in the MASTER project contains the Mission Event Forecast – MEF

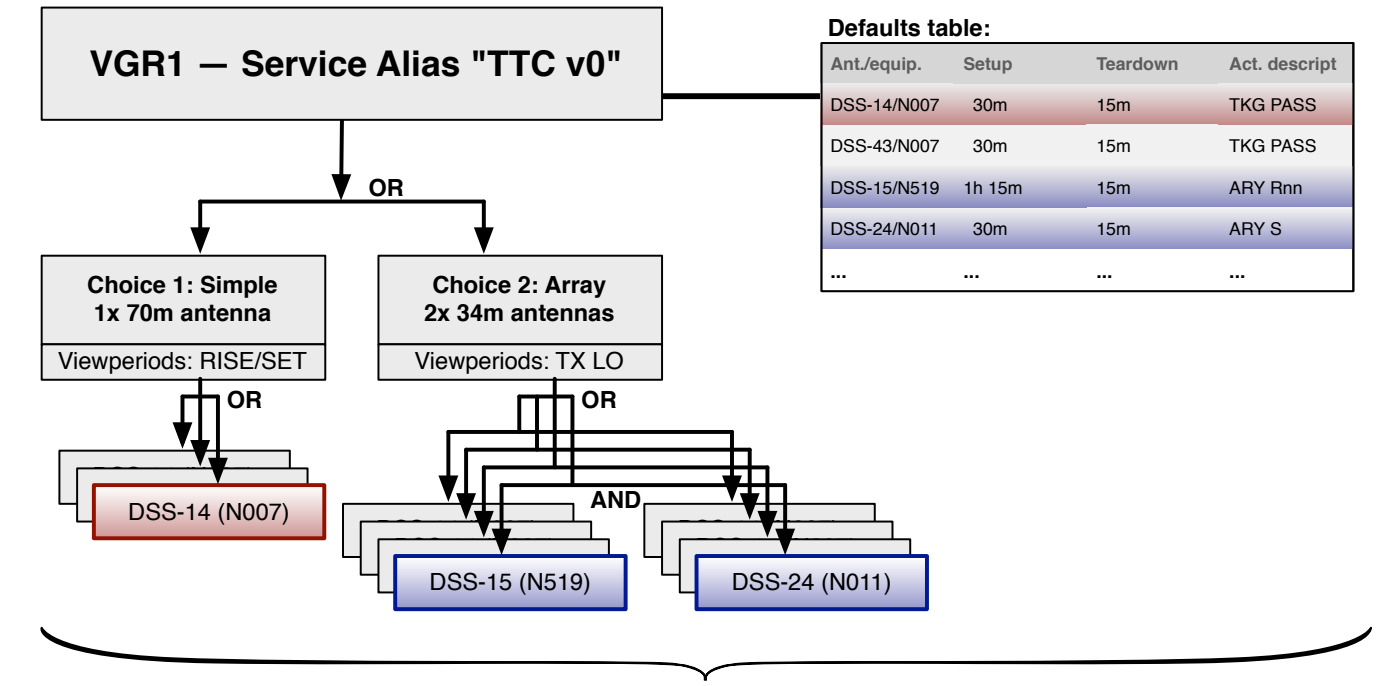


LAPS Data Model – Derived

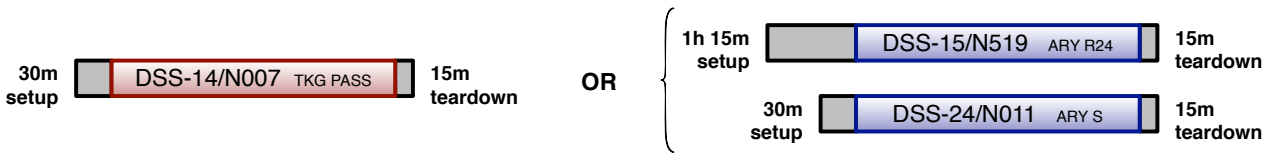


- Scenario computations include:
  - Timeline (Gantt view) visualization of events and requests w.r.t. MEF and downtime
  - ULP (User Loading Profile report)
  - Costing -- aperture fee
  - Projected (forecast) utilization as input to overall network loading
- Only loading is stored in LAPS database – others are computed on demand

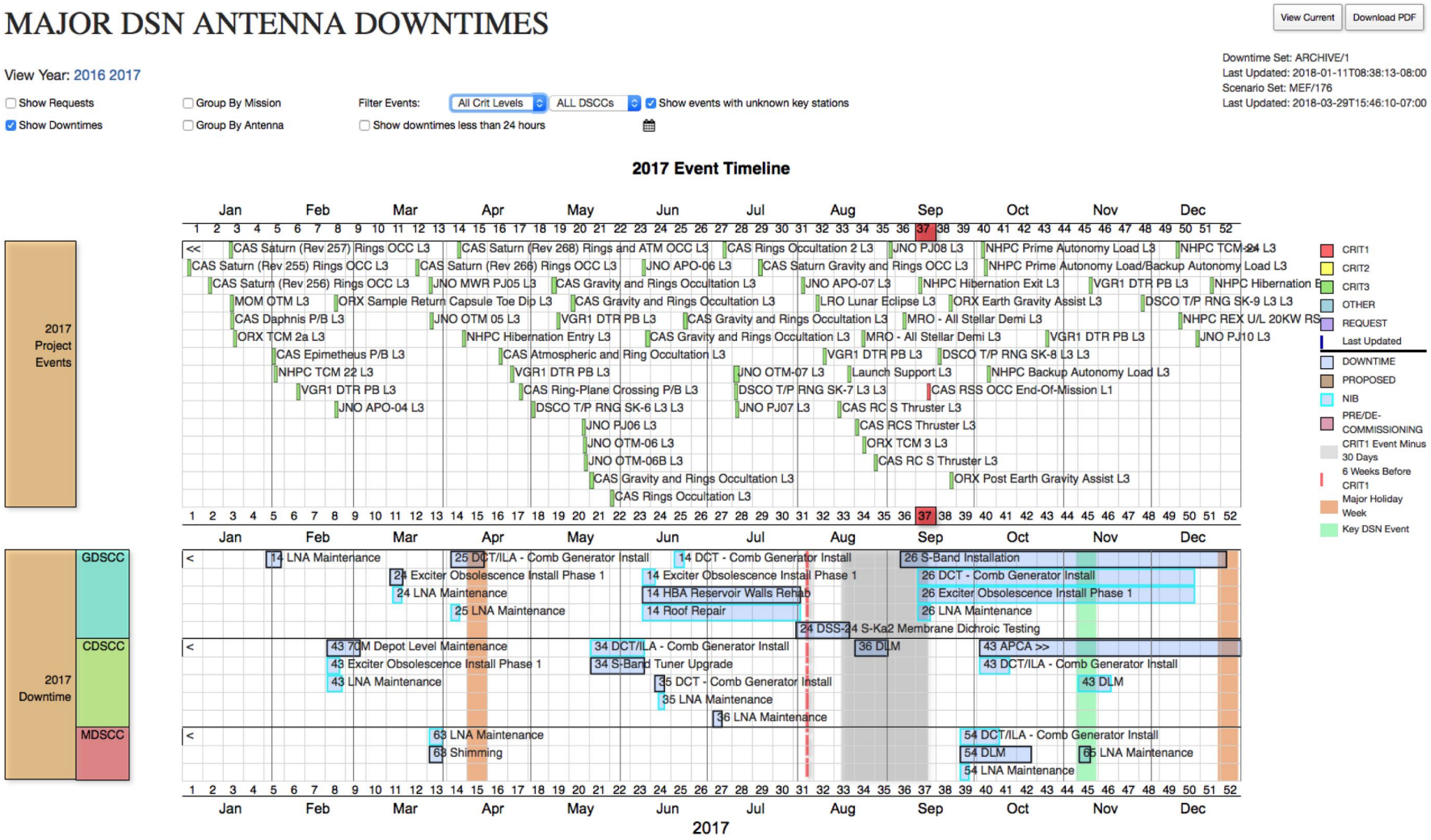
Service Aliases encode asset options



Examples of alternative track instantiations for the same total tracking duration

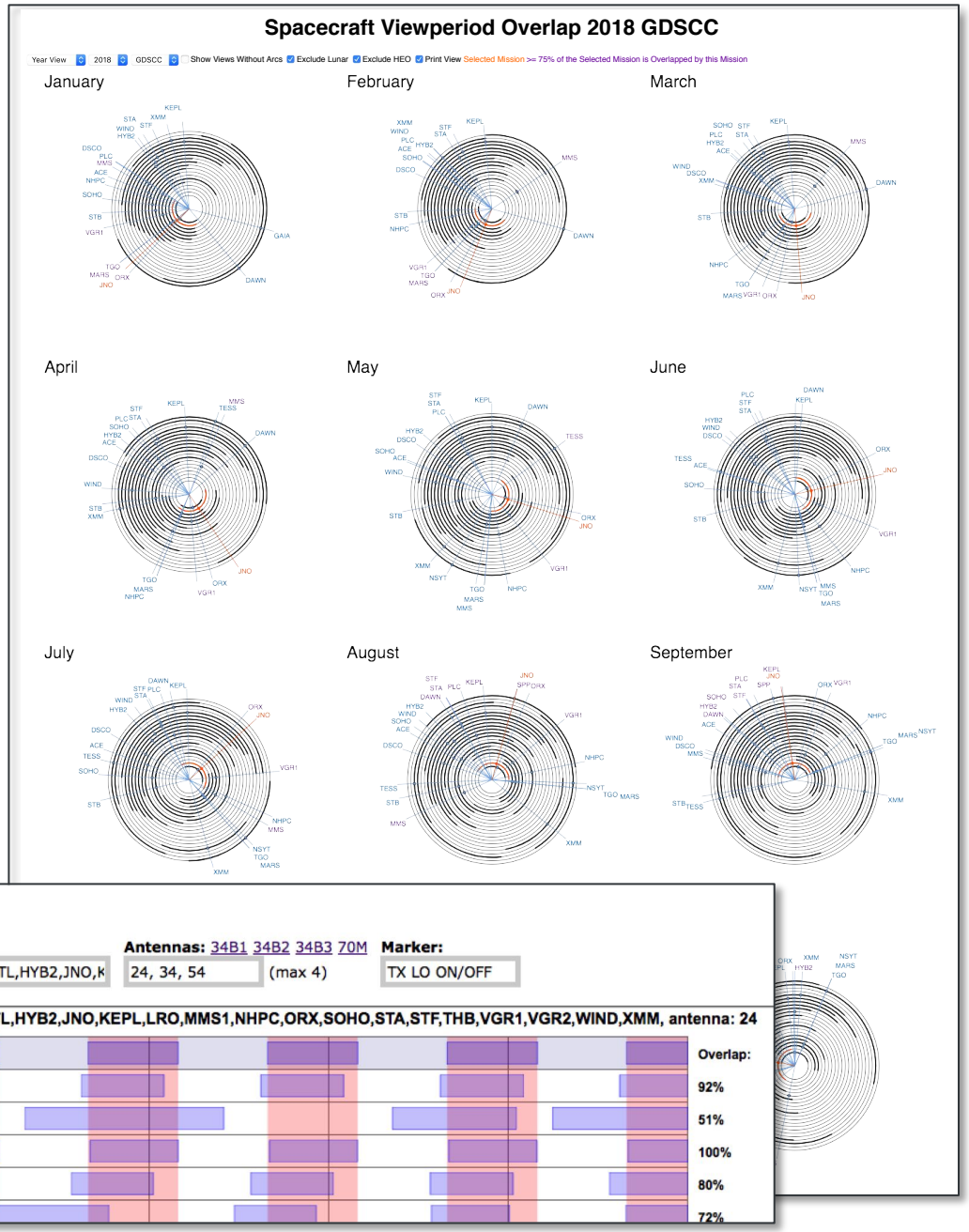


Downtime Planning

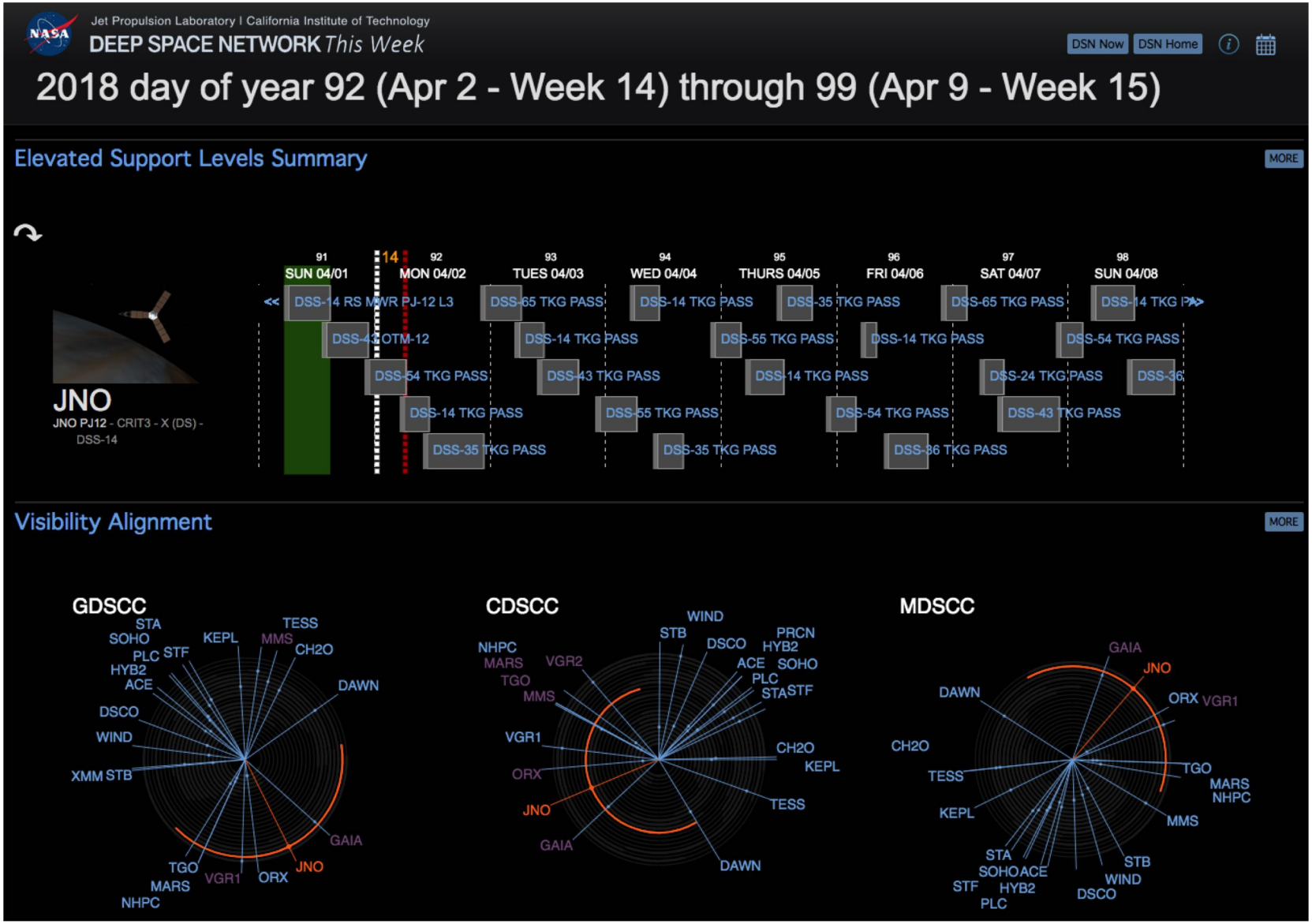


Viewperiods

- Viewperiods are a key factor in network contention
  - seasonal alignment
  - heaviest demand by Mars missions and others
  - some time periods virtually unusable



“DSN This Week”

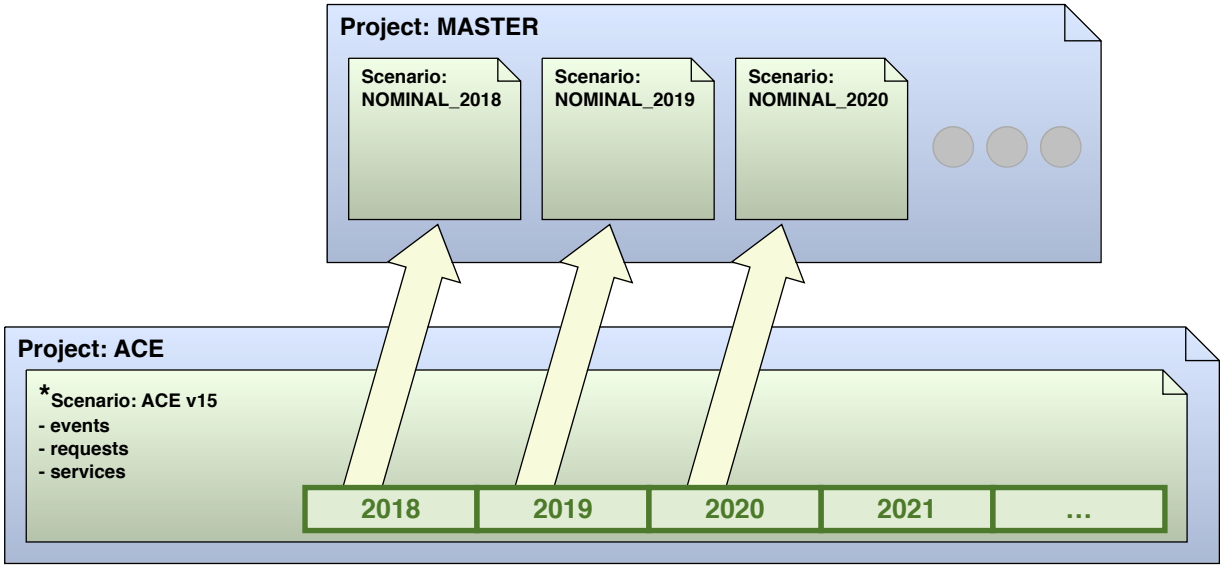


Forecasting Scenarios

- **Changes in mission requirements**: based on new information, often from in-flight experience, there are frequently changes to mission needs that emerge and need to be assessed. Missions submit updates to their planned DSN usage which can be merged with other user inputs to look for potential contention.
- **New missions**: usually associated with proposal calls, missions that are proposing to use the DSN submit their plans for an analysis in context of all other expected users.
- **Downtime studies**: DSN antennas and equipment undergo periodic planned maintenance and upgrades, sometimes requiring months of unavailability that can affect user activities. Studies of alternatives are important to help plan downtimes with the least negative user impact.
- **Asset availability changes**: as antennas are constructed or decommissioned, the impact on mission activities needs to be assessed. This kind of study provides for comparisons of alternatives such as the use of partner agency assets to help with periods of high contention.

Full-scale forecasts

- Forecast runs are broken into one-year chunks
  - ~5 minute run time
  - Source scenarios do not need to be limited: MASTER scenario specifies a time range that is ‘sliced’ out of each mission scenario at runtime



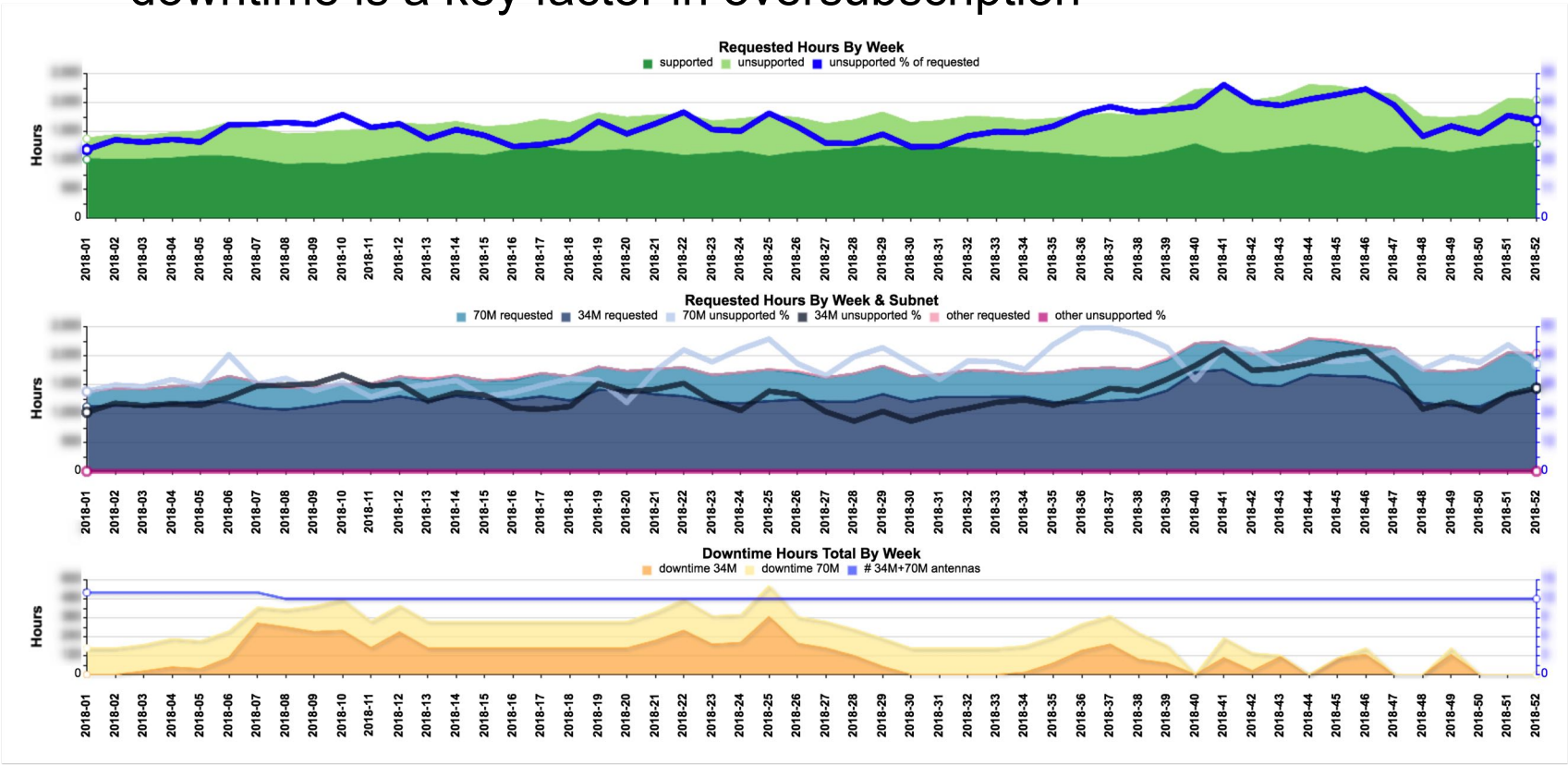
Forecast Runs

A forecast run goes through the following computational steps:

- **For each mission planning request**, determine:
  - constraining time range
  - potential assets (single antenna) or asset sets (multi-antenna configurations, such as arrays)
  - visibility intervals from all potential assets, account for special elevation limits, if any
- **Accumulate** with (initially) equal weight the distributed requested track duration over all the potential asset options
- **Search** over all oversubscribed intervals and adjust weights to lower oversubscription on each asset without making oversubscription worse on any other asset, stopping when there are no further improvements
- **Tabulate oversubscription** by asset group and by mission, for aggregation and reporting

Forecast Results

- Forecast results report total requested tracking time, and how much can be supported within network capacity
  - broken out by antenna type (70-meter and 34-meter), and by mission
  - downtime is a key factor in oversubscription



LAPS Advantages

- LAPS is fast (~5 minutes/forecast year) which allows more alternatives to be explored
- LAPS modeling is more accurate and reflects such capabilities as MSPA and non-standard viewperiod elevations
- All LAPS data is collected in a single unified database where it is versioned and linked to all dependent usages, including all data that can affect the results. This will enable change tracking of user requests as a gauge of system demand.
- The LAPS data model is close to that of S^3, as well as being based on a large amount of shared software, thus enabling the export of planning requests from LAPS to S^3
- LAPS supports direct online editing of planning requests, rather than transcription from spreadsheets; with training, individual mission users will be able to enter, update, and baseline their own planning inputs

Conclusions

- LAPS provides the capability to do extended loading studies, run what-if and trade-off analyses, and assess alternative scenarios for downtime, new missions, and new or changed assets
- The LAPS long-term planning component integrates with and complements the mid- and near real-time scheduling component, Service Scheduling Software (S^3), and the Service Preparation Subsystem (SPS) responsible for predict generation for execution.
- The delivery of LAPS completes the last stage of the plan to replace the DSN legacy planning and scheduling tool collection with a modern, integrated, web-based suite of user-driven applications.