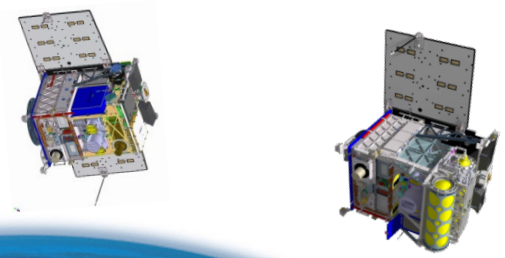
Ground Assisted Onboard Planning Autonomy with VAMOS

Maria Th. Wörle, Christoph Lenzen

German Space Operations Center - GSOC
Deutsches Zentrum für Luft- und Raumfahrt – DLR



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Topics

On-ground vs. onboard planning and scheduling
→ The idea of onboard planning

The FireBIRD mission
→ Environment for VAMOS

VAMOS
→ Components and extension stages
→ On-ground and onboard features
and mechanisms

Conclusion and outlook
→ Future possibilities

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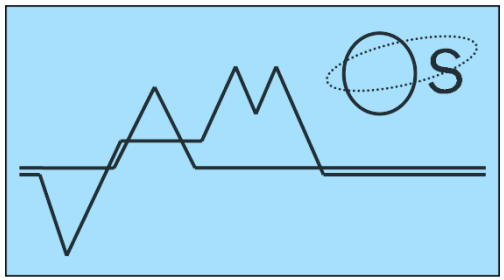

Verification of Autonomous MissionPlanning Onboard a Spacecraft

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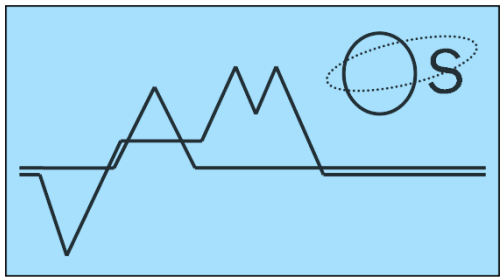

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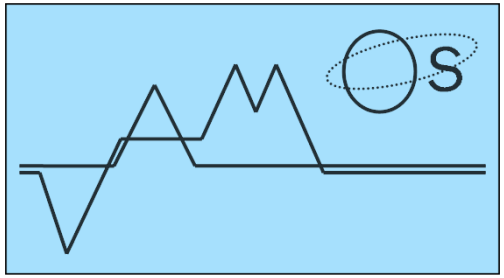

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On-ground vs. onboard planning and scheduling I

Conventional **on-ground** Mission Planning at GSOC for LEO missions:
According to mission, **fully- or semi-automated systems** based on **PLATO/PINTA** with project-specific extensions.

→ Well-proven, **high-sophisticated, high-performance solutions**, incl. e.g.
- well-defined, automated interfaces to customers, ground stations, processing facilities, …
- generation of **„best-possible" timeline** and consistent command sequences with high calculation effort
- detailed **resource profile propagation**

Drawbacks:
- **Lack of predictabiliy** of some onboard behaviour
- **Delay for reactions** to image analysis, detected events etc.

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Idea of Onboard Planning Autonomy:

Distribute **planning and scheduling features** partly to the spacecraft.

→ Maximize the **overall output** of a mission
by using onboard-available information about **real-time telemetry**

→ Enable **enhanced system-reactivity** inbetween ground station contacts
and intervals of on-ground scheduling runs
by processing event notifications

→ **Embedded software** where feasible and helpful

→ Combine with **on-ground created schedules**

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The FireBIRD mission

Two spacecraft:

- **TET-1** („Technologieerprobungsträger-1“), launched July 22nd 2012
- **BIROS** („Berlin InfraRed Optical System“), to be launched in 2014

Mission goals:

- Detection and monitoring of **High-Temperature Events** and additional **Earth observation** tasks
  → multi-functional camera consisting of a bi-spectral infrared hot spot recognition sensor system combined with a three-channel optical sensor
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VAMOS
– Environment and mission-specific challenges

Verification of Autonomous MissionPlanning Onboard a Spacecraft
→ one of the experimental payloads on BIROS

- Embedded in PPU, operating system **RODOS**
- **Real-time telemetry** from SBC and PPU
- Limited memory for storage and computations
- Limited command range
- Limited update possibilities
- High demands on **reliability**
- **Support** of „nominal“/primary mission
- Commanding via **command blocks**, active and passive list

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- Extensive calculation tasks **on-ground**:
  - Generation of **command blocks** (incl. templates)
  - Determination of **extension possibilities and limitations**
  - Thorough **resource propagation, calculation of profiles**
  - Embedded in the general automated Mission Planning System

- **NRT** decisions and modifications **onboard**:
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VAMOS – Two components and extension stages

- **OBoTiS** (OnBoard Timeline Selection)
  - Decision which **pre-commanded timeline blocks** to be activated
  - For each **„Timeline Extension“**:
    one command block + Decision time + Decision criteria

- **OBETTE** (OnBoard Event Triggered Timeline Extension)
  - Add-on to OBoTiS
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OBoTiS – On-ground preparation details I

For **each planning request**, unambiguously **sorted by priority**:

1. **In case** of overlapping, not-discarded planning request of higher priority with later or equal starttime: **discard** the planning request.
2. *Decision time = starttime – 1sec*
3. For each resource:
   a) **propagate profile** with inserted request,
   b) derive **extension condition** as: *maximally allowed value = propagated value at decision time + „minimum remaining availability“*
4. Add **composed timeline extension** to to-be-commanded set
5. **In case** no overlapping timeline extension of higher priority created before, **keep current profile modifications** (start was empty base timeline), **otherwise reset** them.

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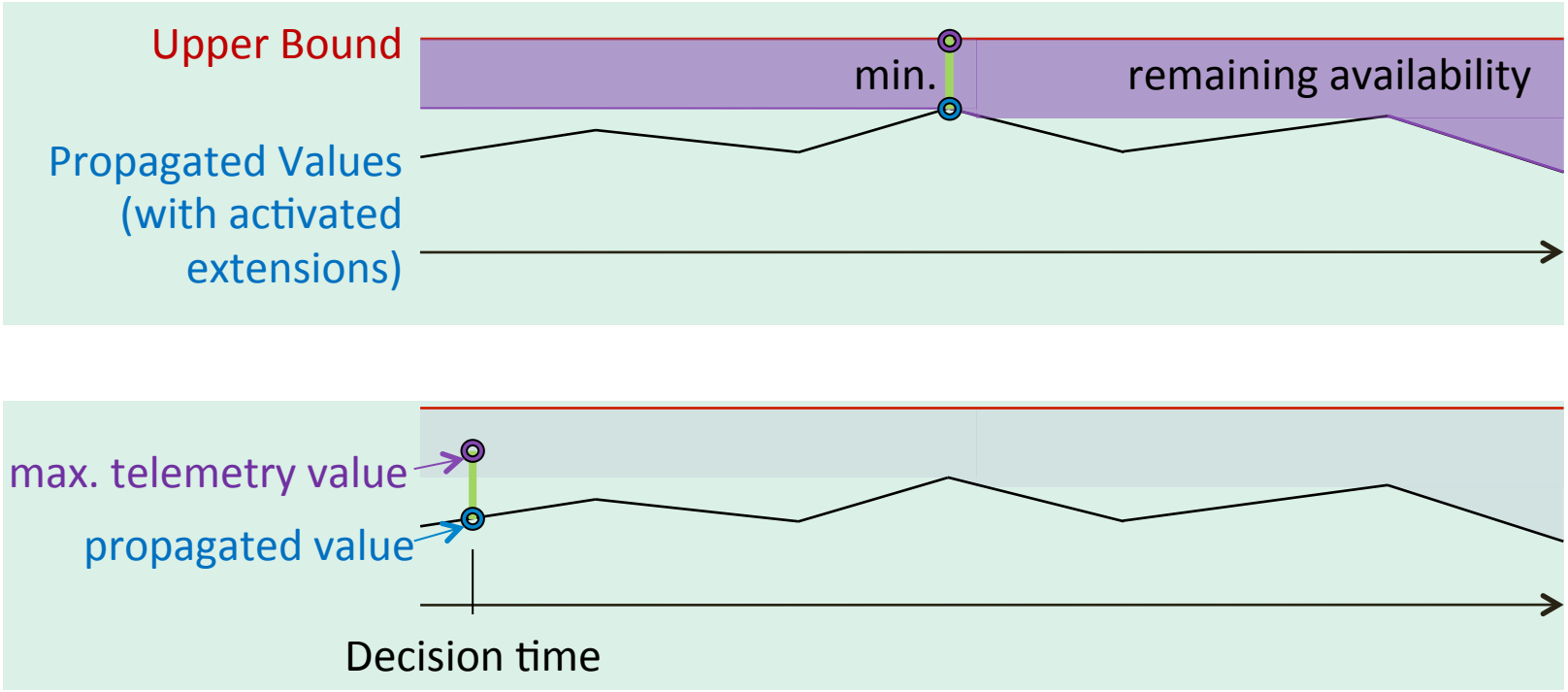
OBoTiS – On-ground preparation details
– Deriving of conditions I

Determination of maximum telemetry value:



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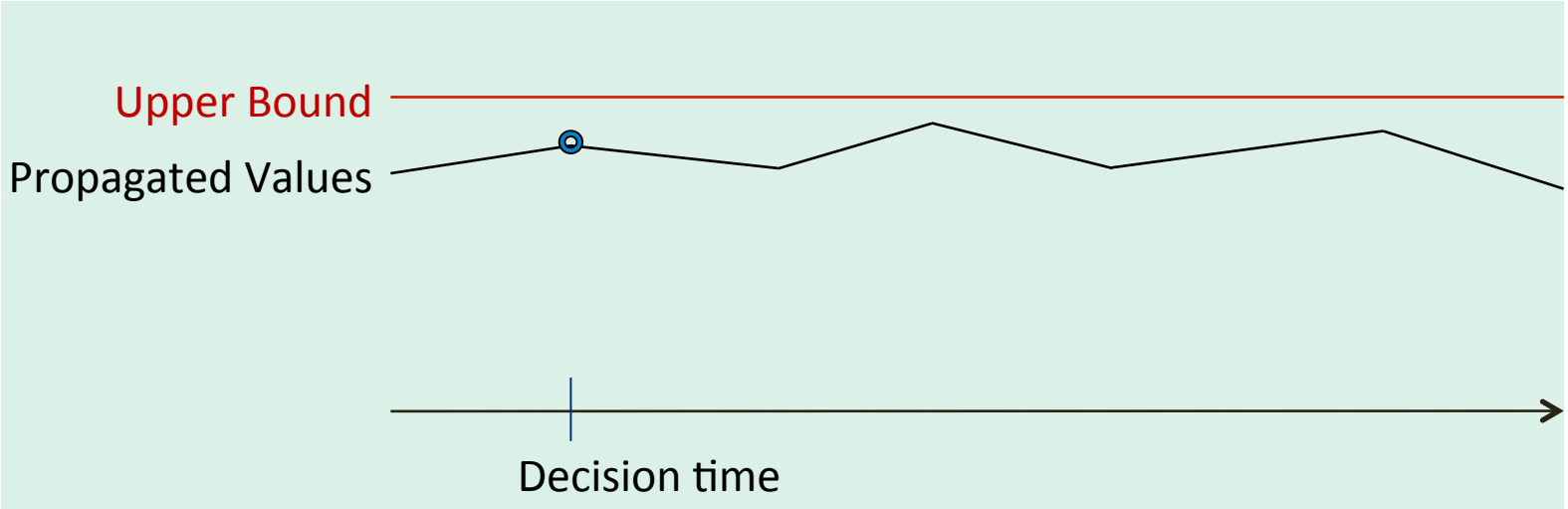

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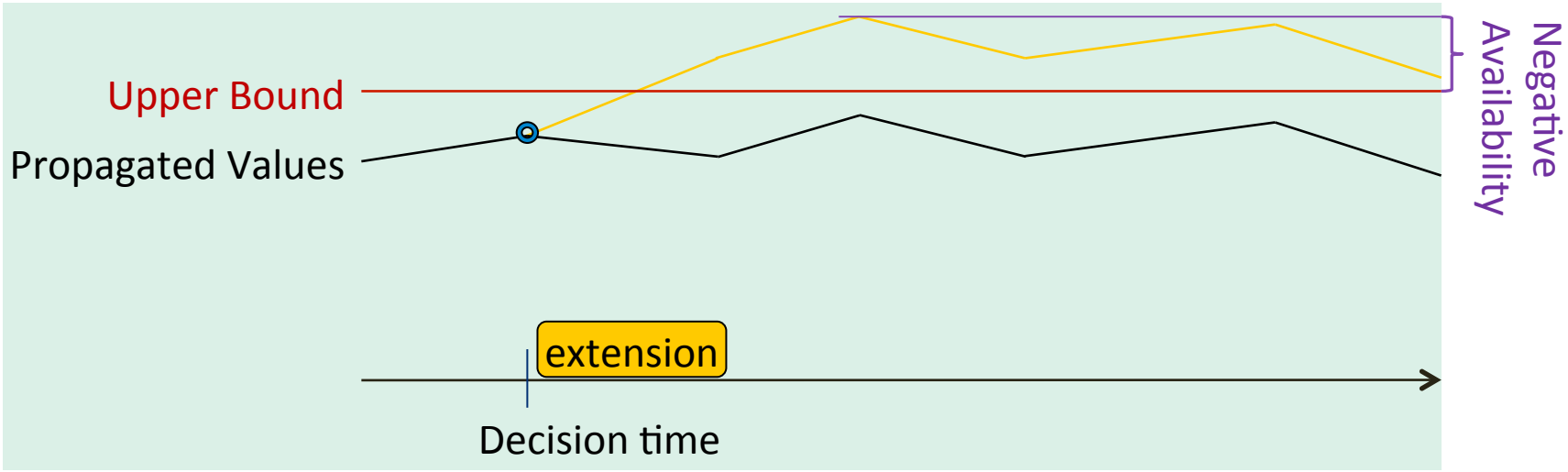

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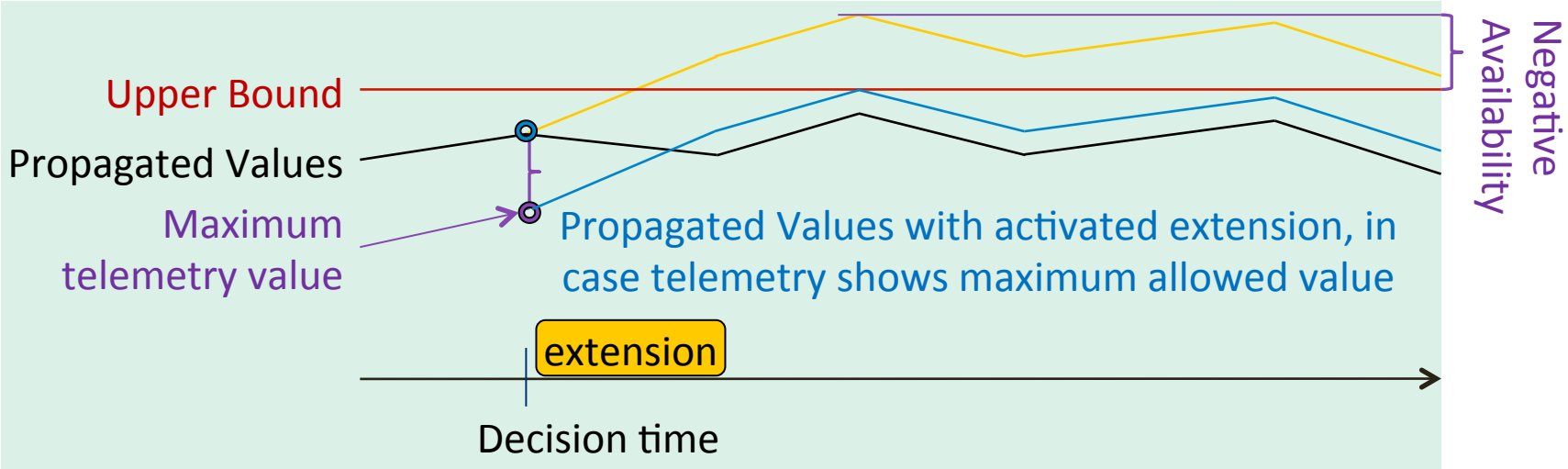

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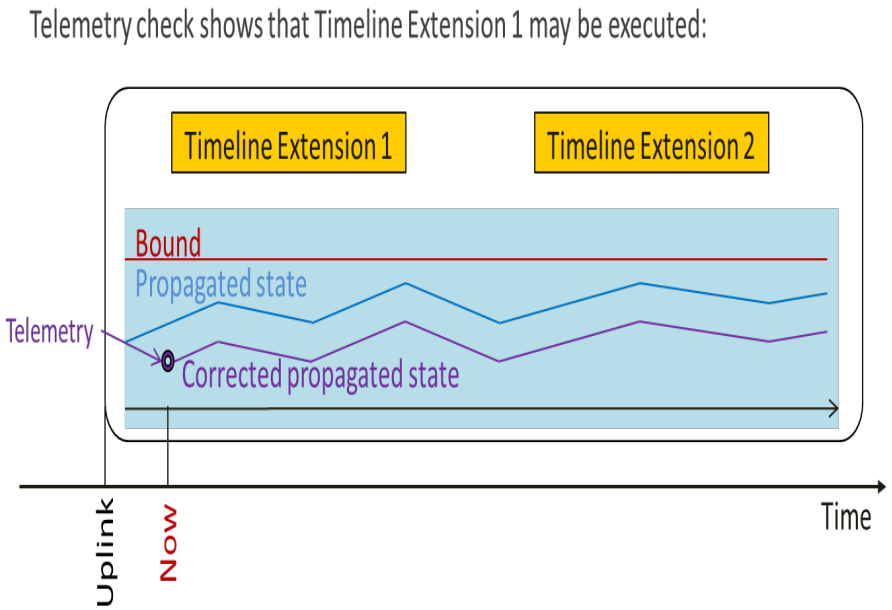
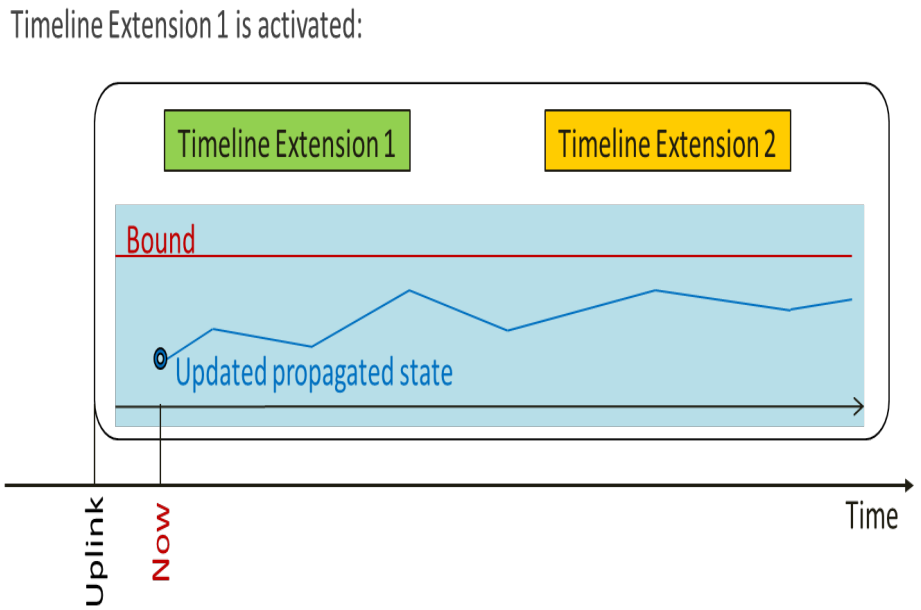
OBoTiS – Onboard mechanism

→ Activate command blocks via ID,
after **checking set of telemetry conditions** at decision time





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To be **generated on-ground** and **commanded** to the spacecraft:

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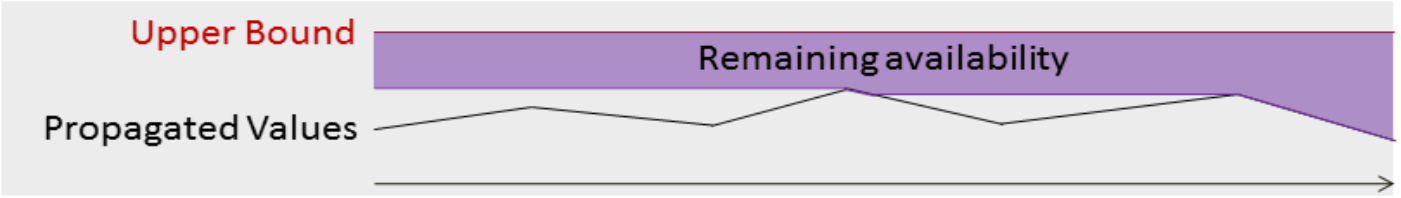
- on-ground *"propagated values profile"*
- template command block(s)



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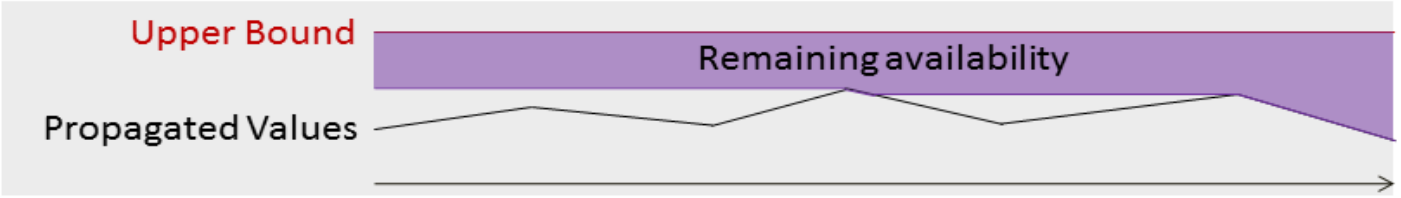

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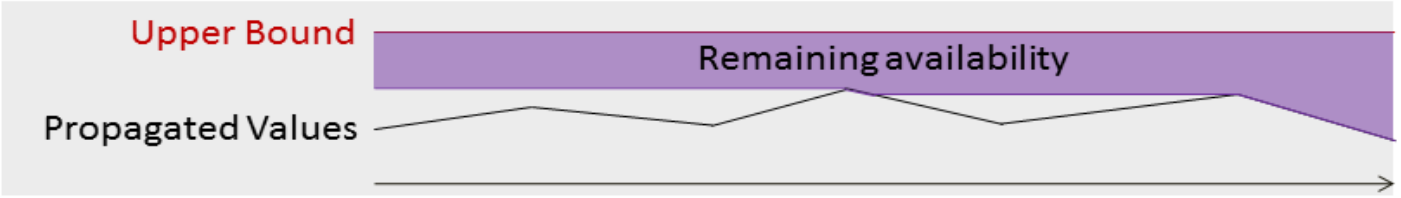

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1. Filling **event parameters to extension template(s)**
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4. *Remaining availability including this extension*
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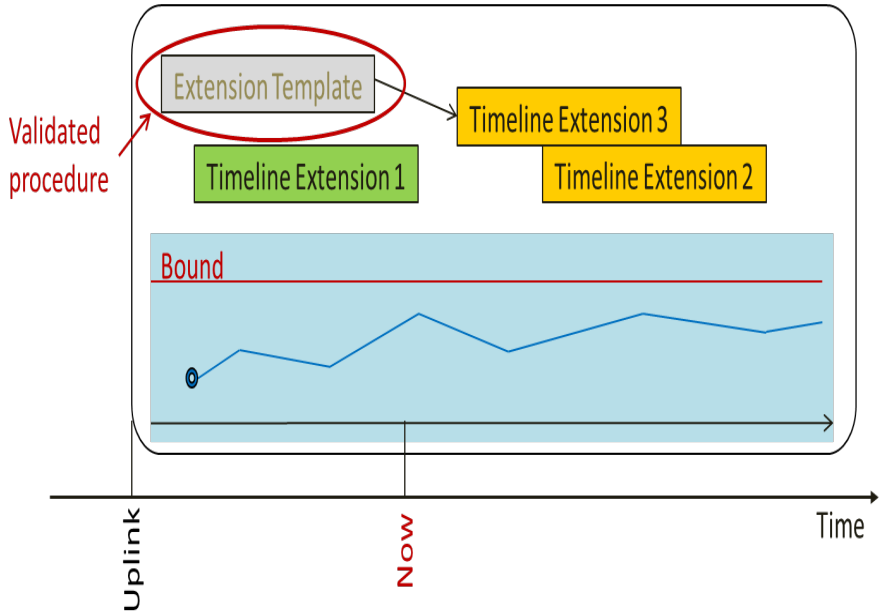
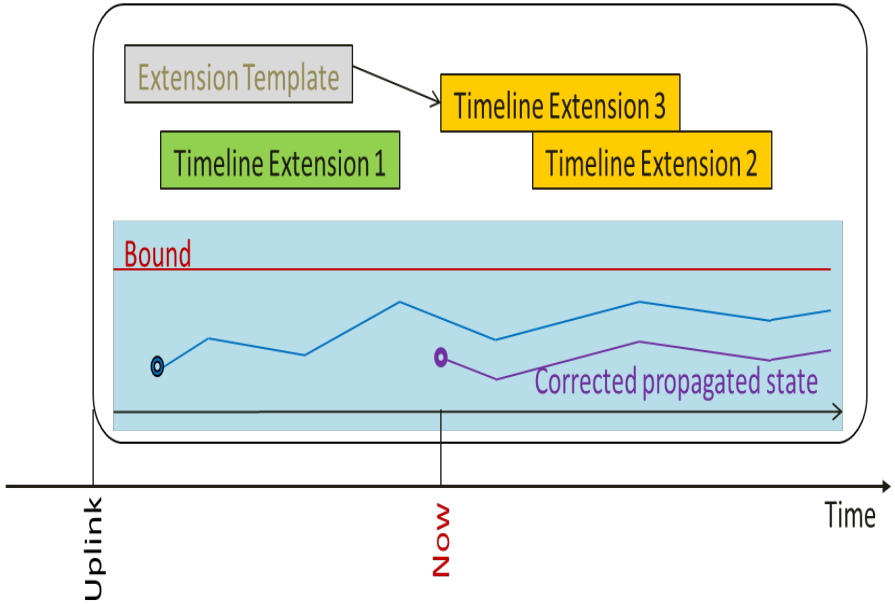
OBETTE – Onboard mechanism II

6. Add new timeline extension(s) to the assortment for OBoTiS

External event triggers generation of new Timeline Extension 3 from template:



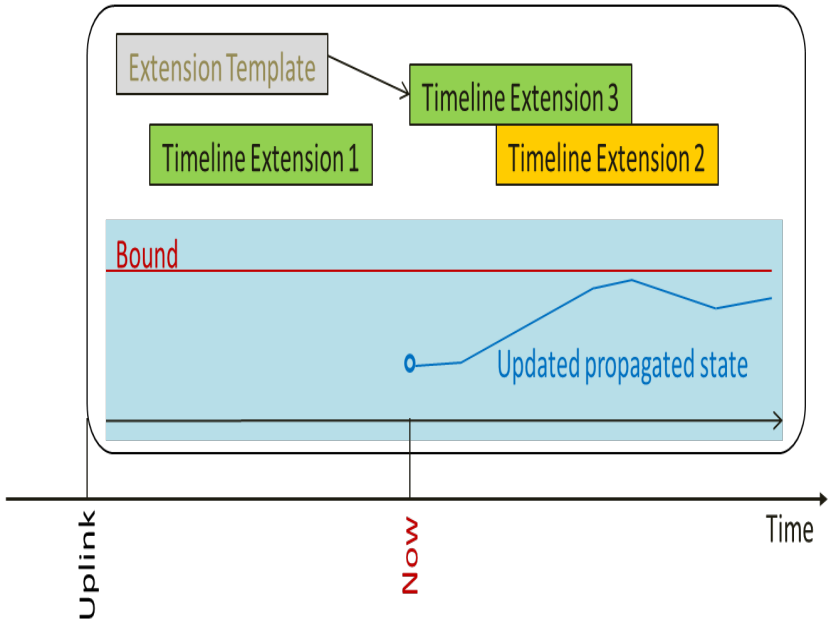
Telemetry check shows that Timeline Extension 3 may be executed:



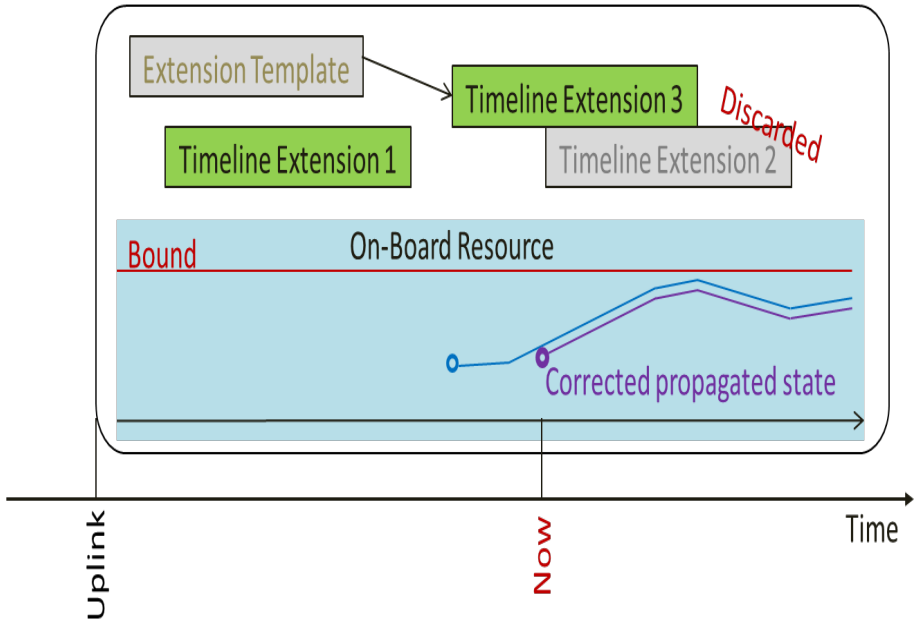
OBETTE – Onboard mechanism III

Behaviour after extension activation:

Timeline Extension 3 is activated:



Telemetry check shows that Timeline Extension 2 cannot be executed:



Conclusion and Outlook

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- Elaborate approach to **enable combination** of Earth observation and „Earth watching“ with relatively simple **onboard component**
- Stepwise testing and activation with **operational use** in case of success
- **Verification** of such a technique as important step to application in **future non-experimental projects**
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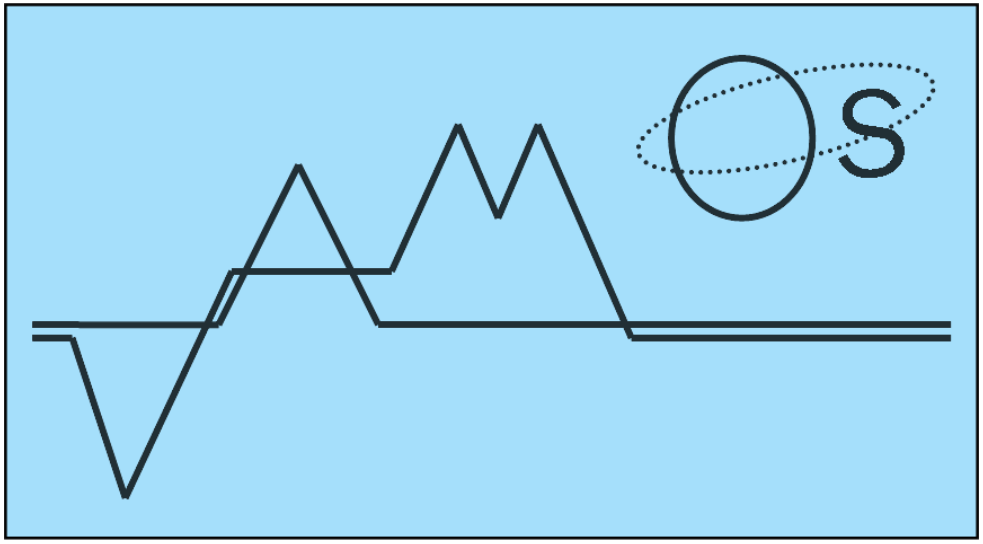

Any questions?

Thank you for your attention!

DLR