Coping with flexibility requirements in ASTRO APS star tracker software

Ingolf Steinbach, FSW 2013, Pasadena CA, 2013-12-10

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Jena-Optronik GmbH

Jena-Optronik focuses on space applications with operational, commercial and scientific background:

- **Attitude and Orbit Control Systems (AOCS) sensors:**
  - Star Sensors
  - Rendezvous and Docking Sensors
  - Sun Sensors
- **Optical space instruments for Earth observation :**
  - Multi-spectral imager JSS 56
  - Imaging Radiometer METimage
  - Important contributions within Sentinel-2, Sentinel-3 & Sentinel-4
  - Multi-spectral filter assemblies
- **Software and data processing**
- **Awarded excellent products:**
  - Boeing “Supplier of the year 2006”
  - Astrium “Master supplier 2007”
  - Mitsubishi Electric Corporation “Certificate of Appreciation” 2009
  - Mitsubishi Electric Corporation “Best Supplier Award” 2011
- Jena-Optronik is EN/AS 9100 certified

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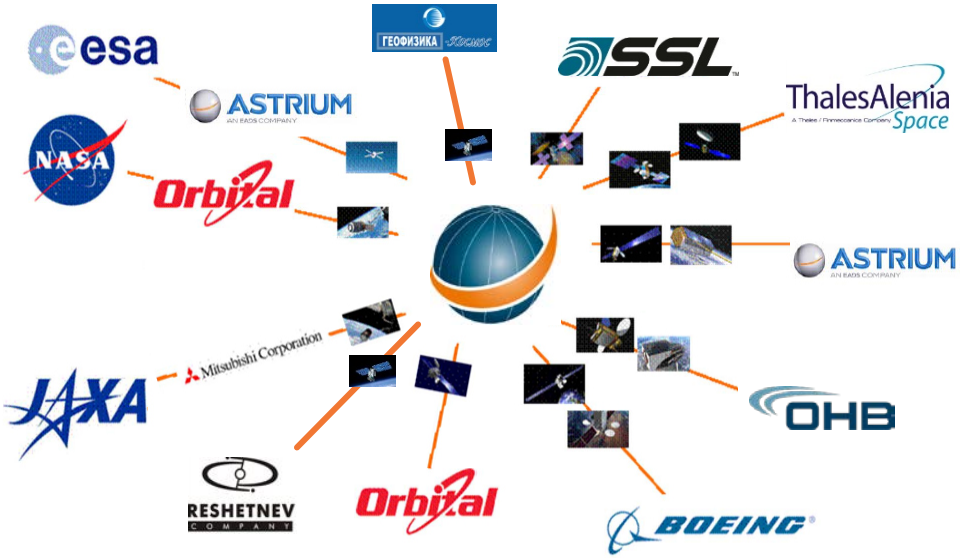
The company.



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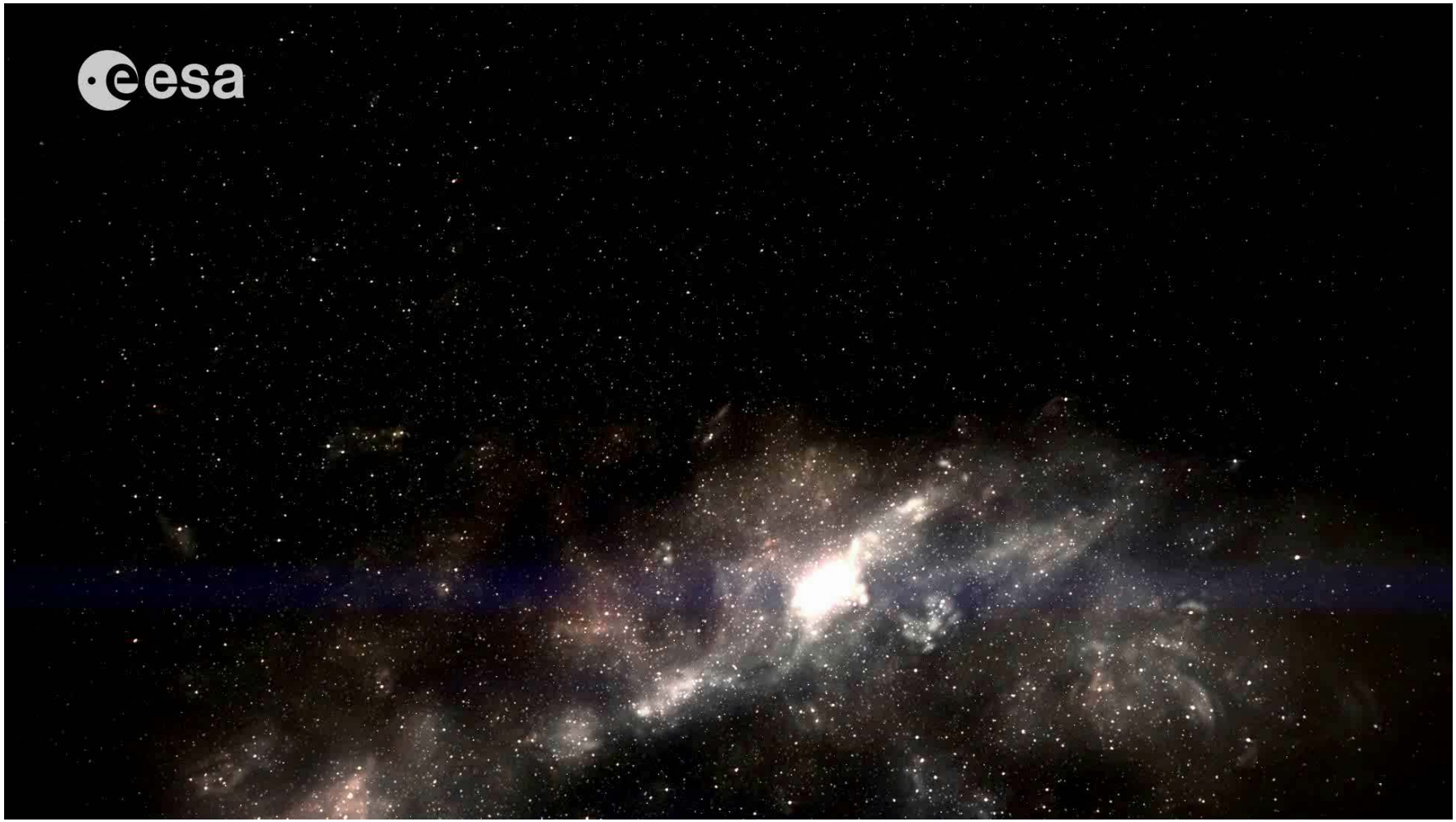
Star Tracker Tasks



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Highlights of ASTRO APS

Photo ©ESA

- Active Pixel Sensor (APS) technology
- Lifetime > 18 years
- Radiation design for 25 years GEO environment
- Space qualified CMOS detectors
- Full performance with moon in the field of view
- Very robust against solar flare environment and false star objects
- Attitude accuracy [LSFE, HSFE, TE]:
  - < 1 arcsec [1σ] xy-axes
  - < 8 arcsec [1σ] z-axis
- Mass: < 2kg (incl. straylight baffle)
- **In space since July 2013 (on board Alphasat)**
- **… and performing excellently!**

Configuration options with major impact on software

Operational interface:

- MIL-STD-1553B
  - ESA PUS (ECSS, CCSDS Source Packets based)
  - Low Bandwidth Jena-Optronik (“JOP”) Protocol
- RS422 based UART
- SpaceWire
- SCDI (Synchronous Serial Command & Data I/F)

Detector:

- STAR1000
- HAS2

Operating System:

- RTEMS (for real hardware)
- Solaris / Windows (for simulators)

Typical supplier challenge

- Customers:
  - “Star tracker must integrate smoothly into on-board data handling”
  - Varying bandwidth limitations
  - Manifold operating scenarios (GEO vs LEO, agility, …)
- Product manager:
  - Uniform product line desired
  - Minimum impact of options on the characteristics
- Both:
  - Qualification status to be kept as much as possible

First thought: “Clone and own”

- Obvious benefits:
  - Quick
  - Customer requirements can easily be integrated
  - No impact on other projects to be considered

- But…
  - No other projects are considered
  - Projects will slowly diverge
  - Heritage is obscured
  - No easy benefit from improvements in other projects
  - Potential configuration nightmare

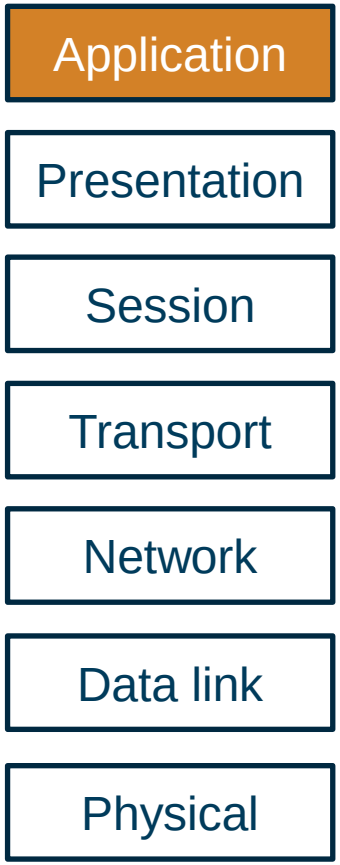
Upon second thought (Jena-Optronik approach): Modularization

- Use same core parts (e.g. algorithms) in all configurations
- Communication Protocol Stack according to OSI
  - Protocol layers exchangeable
  - Each configuration can use a different selection
- Low-level drivers with abstract interface for hardware parts (HAL)
  - Same abstract interface can be implemented by different drivers
- Operating System Abstraction Layer (OSAL)
  - Implementation of abstract concepts for different operating systems

Application Layer

- Implements high-level star tracker concepts (aka “services”)
  - Initial acquisition
  - Attitude tracking
  - Health monitoring
  - …
- Includes definition and purpose of parameters

- Identical in all configurations
- Described in a generic user manual



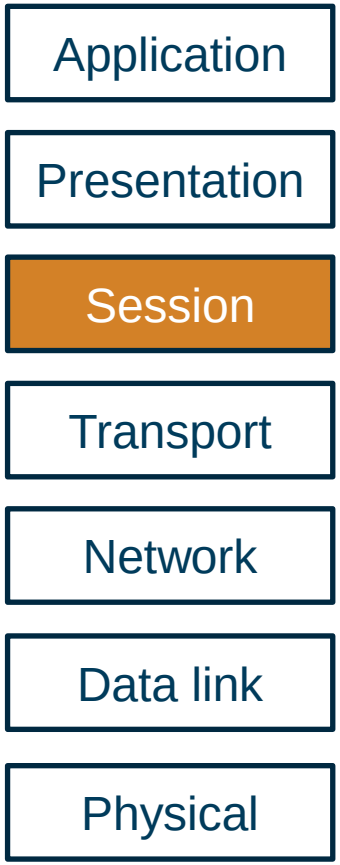
Presentation Layer

- Defines data structures, for instance
  - Telemetry data blocks
  - Telecommand parameter structures
  - Selected internal data structures
- Includes encoding of parameters
- Up to now, identical baseline in all configurations
- Can be augmented (e.g. PUS requires additional services)
- Described in "measurement and command list" (part of the Software ICD)

Application
Presentation
Session
Transport
Network
Data link
Physical

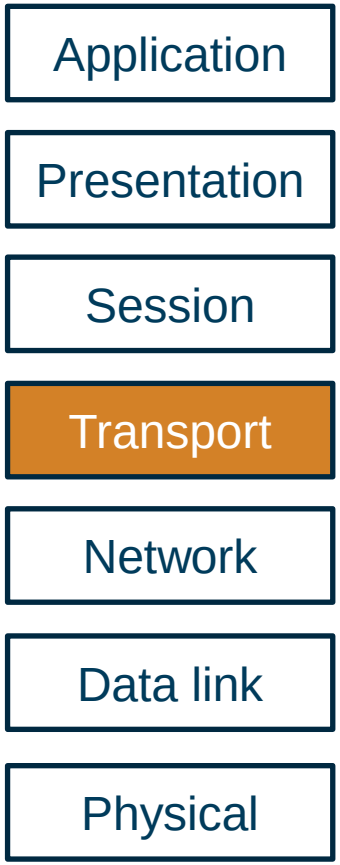
Session Layer

- Implements
  - Packeting/depacketing of TM/TC data structures
  - Sequence counters
  - Integrity checks (CRC based)
  - Completeness checks
  - …
- Two alternatives:
  - Low bandwidth Jena-Optronik ("JOP") session layer
    - Suitable for all communication media
  - ESA PUS (using CCSDS TM/TC source packets)
    - Currently for MIL-STD-1553B configurations
- Described in dedicated part of the Software ICD



Transport Layer

- Implements
  - Serialization / fragmentation (if necessary) of telemetry
  - De-serialization / reconstruction of telecommands
  - Handshaking
  - …
- Typically: implementation(s) specific for each media type
- For MIL-STD-1553B, two alternatives:
  - Data block transfer (serial, ECSS-E-ST-50-13C)
  - Jena-Optronik (random access, low bandwidth)
- Described in dedicated part of the Software ICD

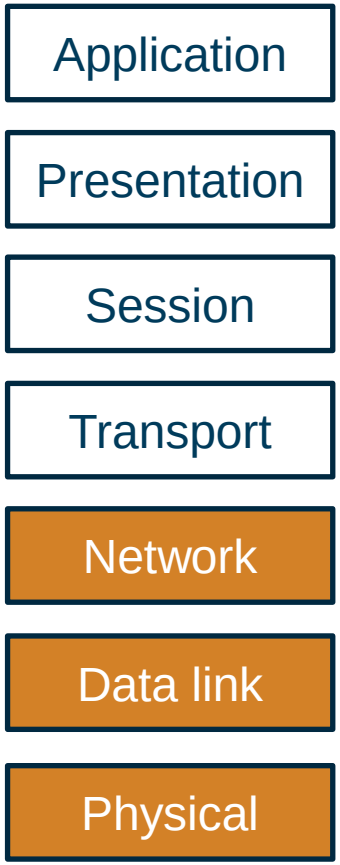


Network / Data link / Physical Layer

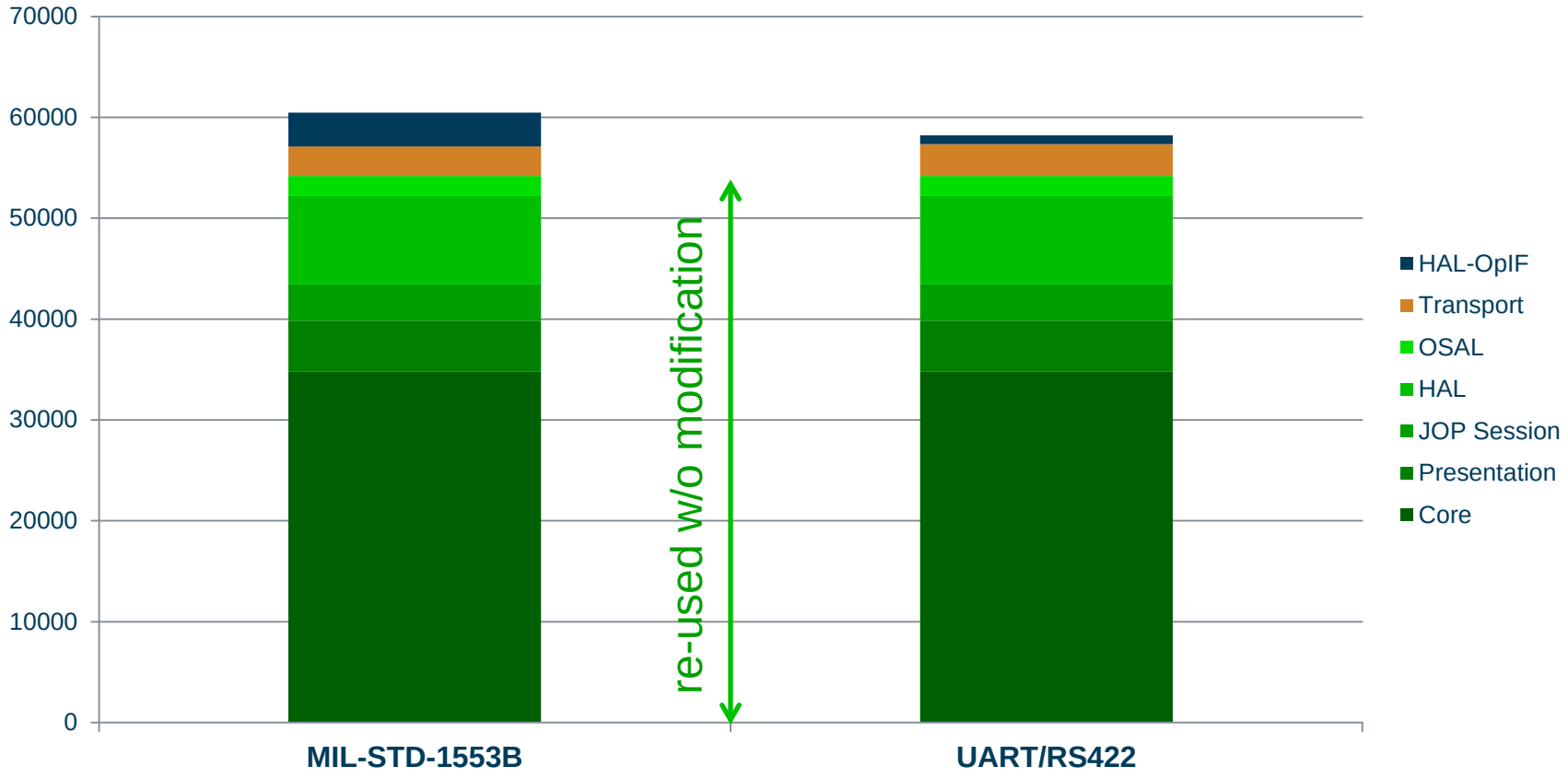
- Functionality partially provided by dedicated controller hardware / associated electronics
- Augmented by low-level software drivers

- Drivers located in Hardware Abstraction Layer (HAL)
- HAL provides abstract interface to upper layers

- When exchanging controllers (for same media type):
  - Abstract interface *not* impacted
  - New implementation of abstract interface
  - Transport (and upper) layers *remain unchanged*



Re-use in 2 Sample Configurations (Lines of Code)



Benefits for validation

- Cleaner design
- Stubs for each layer available for development & testing
- Tests implemented e.g. for
  - Session layer only (CPU emulator)
  - Transport layer only (CPU emulator)
  - Low-level driver (extended emulator and/or real hardware)
- Most of the protocol stack testable w/o communication hardware
- Easy error injection at different layers
- Coverage of 100% MC/DC “more than” achieved
- Simulators for the star tracker:
  - Processing algorithms only
  - Processing + (part of the) protocol stack

Benefits for the user

- Evident qualification status

- One user manual (independent from communication interface)
- Interface Control Document with separate sections for
  - Measurement and command list
  - Session layer
  - Transportation layer
  - Project specific information (if necessary)

- Supports layered approach at the user's site (but does *not* enforce it)
- Easy identification of required changes when migrating from one medium to a different one

Evaluation of the modularized approach

Drawbacks:

- More design effort needed
- Refactoring necessary when introduced in existing code
- Short-term: higher costs

Benefits:

- Mid-/long-term: less costs
- Clean design
- Consistent behavior of the star tracker between configurations
- Ideal testing/simulation capabilities
- Small delta qualification when porting to different protocol stacks
- High flexibility

Questions?

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