Onboard Data Handling

Gert Caspersen

Terma A/S

gec@terma.com

TERMA^{T}
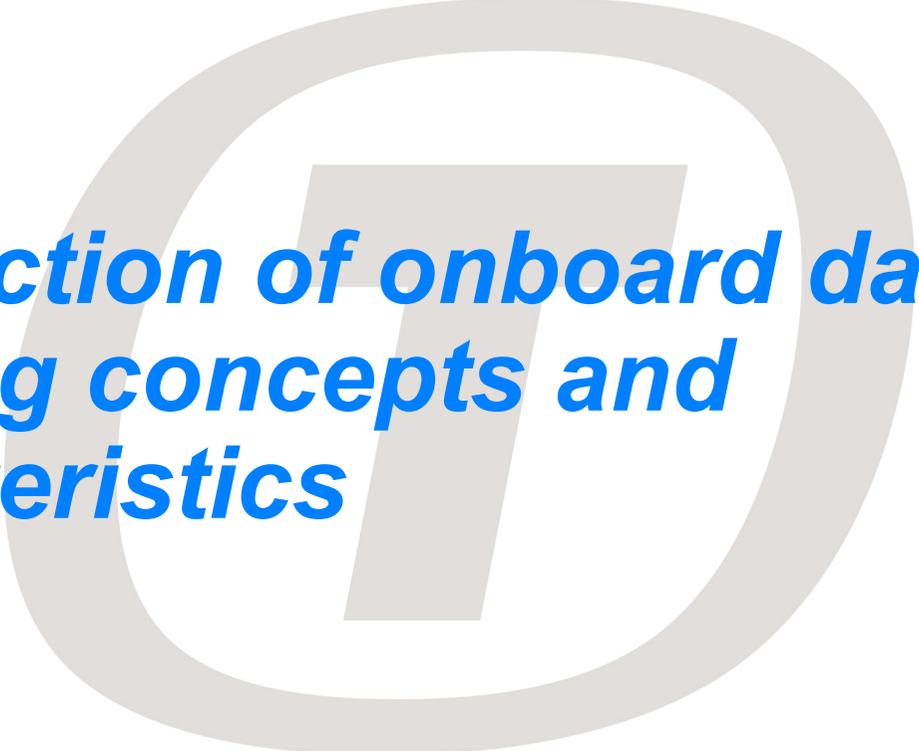
Introduction of onboard data handling concepts and characteristics

What Will be Said

- Satellite Elements
- Characteristics
- Purpose
- Operations
- Logical Model
- Architecture
- Functions
- Ørsted onboard data handling
- Robustness
- Software Development
- Pitfalls
- Résumé

Satellite Elements
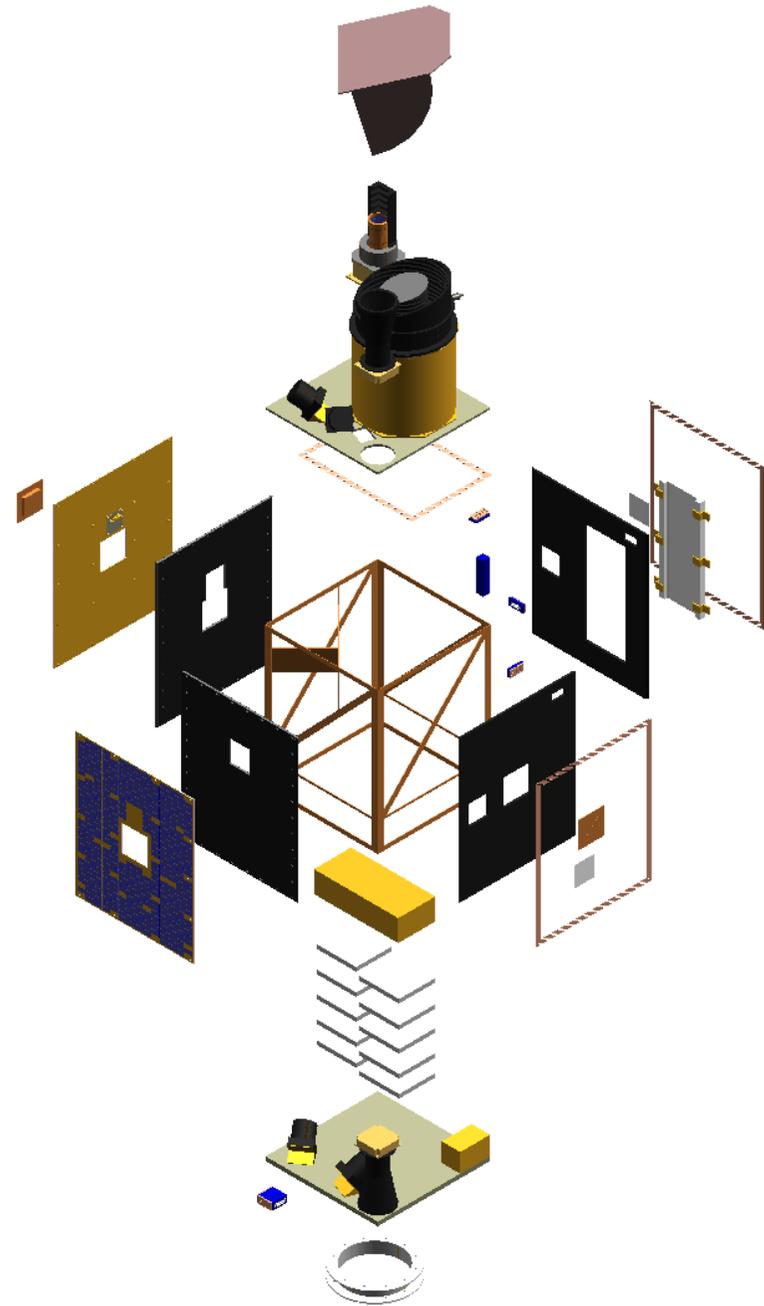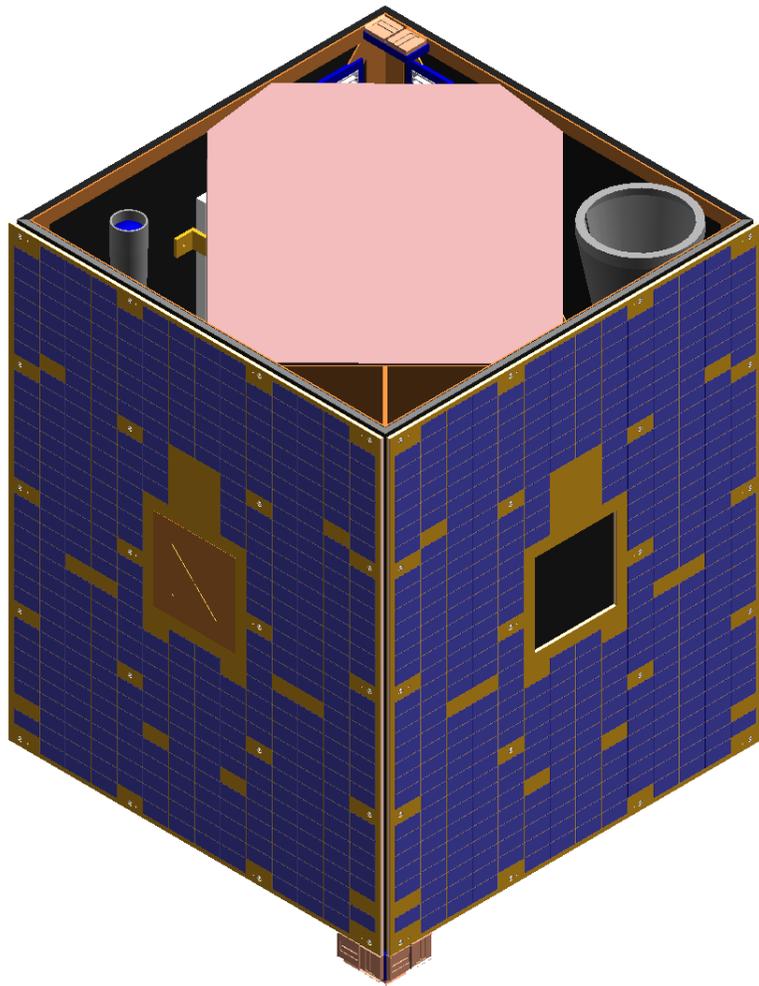
Purpose

Logistics

– **Power distribution**
– **Commanding**
– **Time synchronisation**
– **Status reporting**

Communication

– **With ground**
– **On satellite**

Autonomy

– **Handle platform & payload without ground contact**

Anomaly Handling

– **Maintain mission objectives**
– **Prevent loss of satellite**

TERMA

Characteristics

Limited Resources

– **Processing power**
– **Memory**
– **Bandwidth on busses**

Embedded Real-Time Software

– **Hard real-time requirements**
– **Numerous events & actions**
– **Boot-strap software & application software**
– **No operating system (bare platform)**

Hostile Environment

– **Fault prevention**
– **Fault tolerance**

Operations

TERMA®

Operations Procedures

Command Time Line

Satellite

Operators

Spacelink

Control Centre

Ground Station

Network
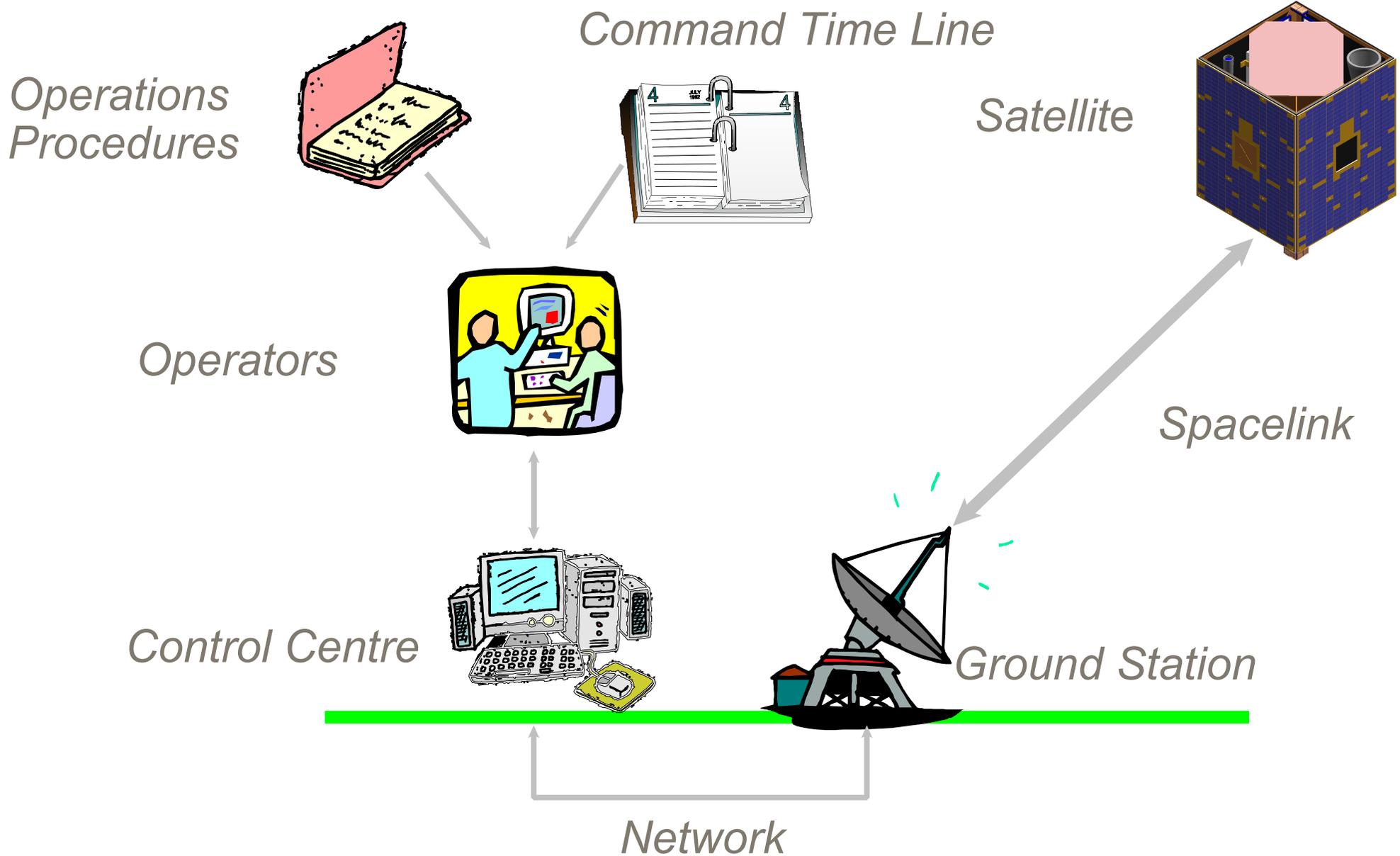
Rømer Data Handling Context
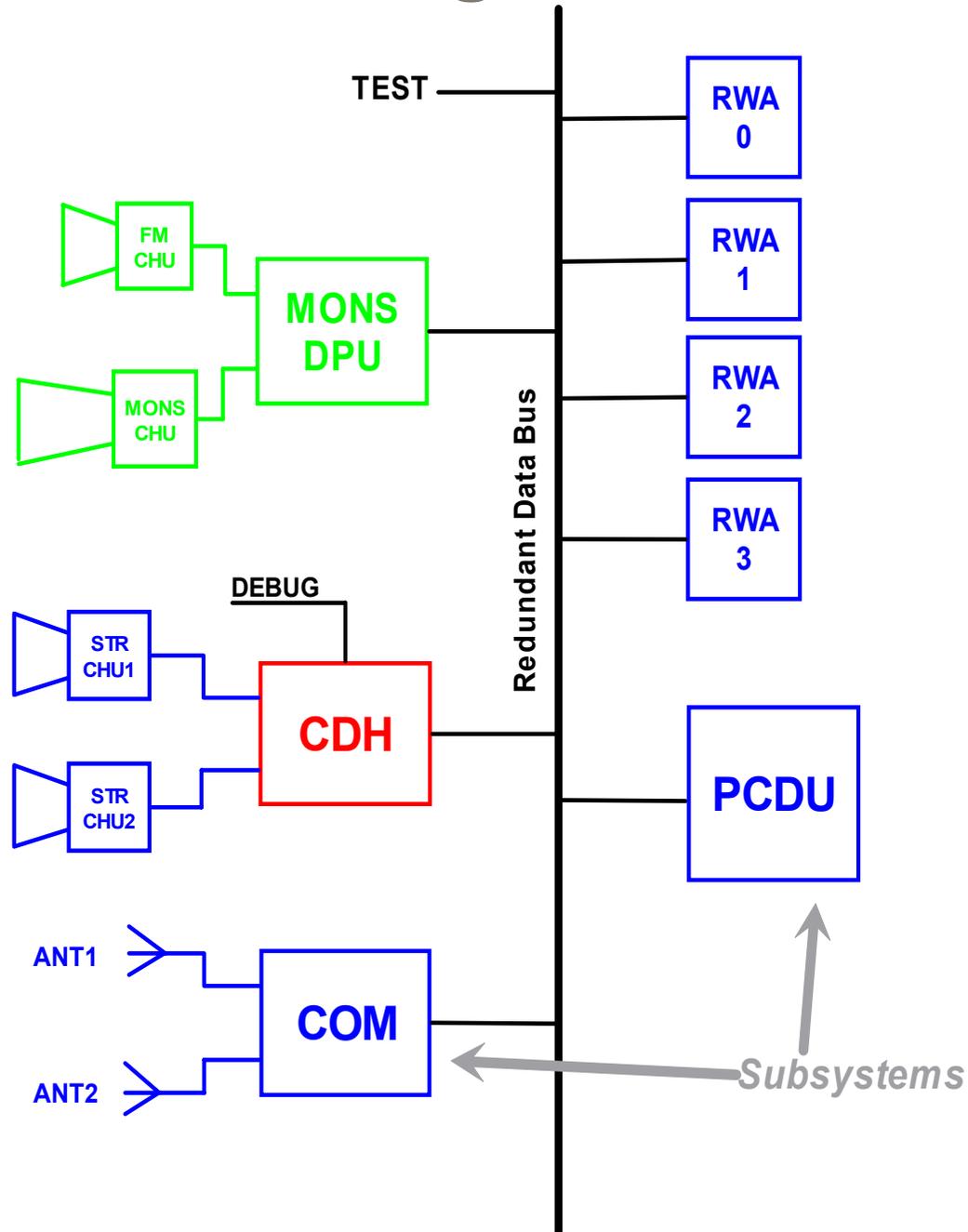
Exercise: The Black Box

Perceive a computer with a piece of embedded software.

It is a block box revealing only a limited amount of status information.

What status information shall be available to assess the integrity of:

1: Hardware

2: Software

Logical Model: Abstraction

Service Provider 1

Service Provider 2

...

Service Provider n

Service Request

Service Reports

Onboard Traffic Management

Service Requests

Service Reports

Service User 1

Service User 2

...

Service User n
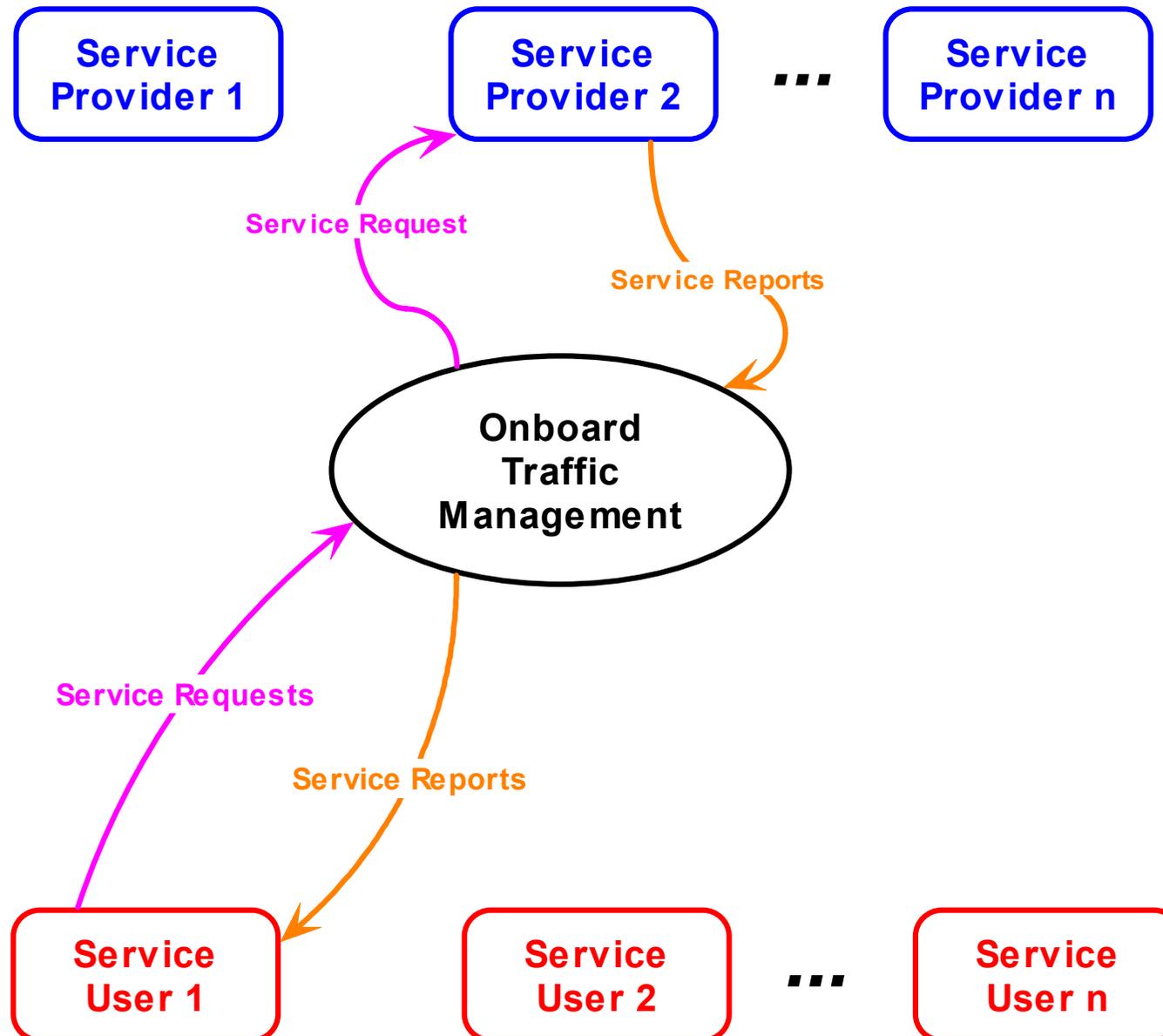
Logical Model: Implementation

TERMA^{T}

Space Segment

Remote Subsystem

Local Subsystem

Provided Services

Provided Services

Provided Services

Application Process 1

Application Process 2

...

Application Process N

Telecommand

Telemetry

Onboard Traffic Management

Data Handling & Control System

Telecommand

Telemetry

Control Centre 1

Control Centre 2

...

Control Centre N
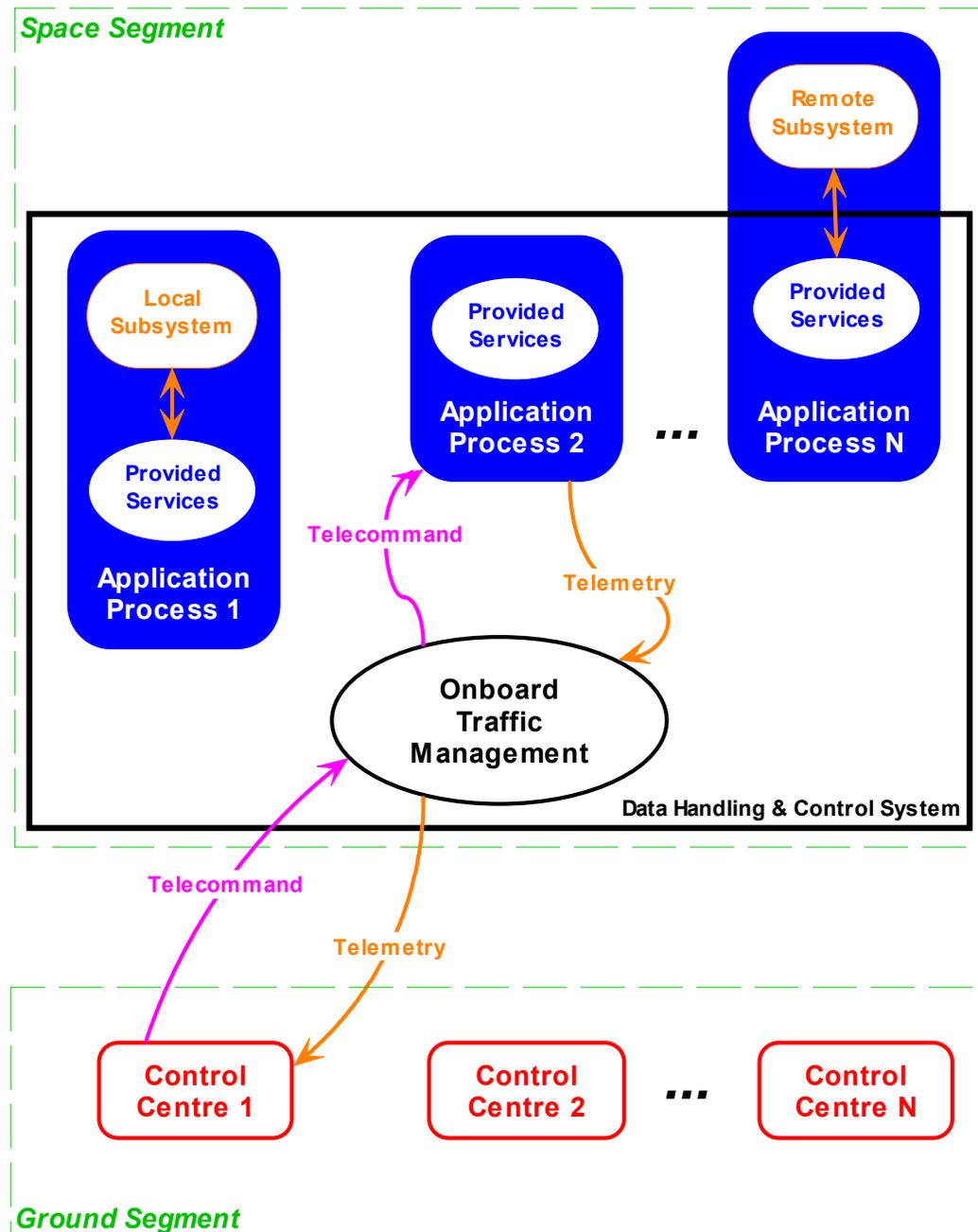
Ground Segment

ESA Standards

Packet Telecommand Standard

– **Protocol for uplink: Ground segment ➢ Space segment**
– **Stream of *telecommand packets***

Packet Telemetry Standard

– **Protocol for downlink: Space segment ➢ Ground segment**
– **Stream of *telemetry packets***

Packet Utilisation Standard

– **Application layer: Ground segment vs. Space segment**
– **Logical model for satellite operation**

Telecommand/Telemetry Formats

TERMA©

Telecommand

Head   *Tail*

Destination ID	Sequence Counter	Command Type	Data	Checksum

Telemetry

Head   *Tail*

Originator ID	Sequence Counter	Telemetry Type	Time Stamp	Data	Checksum
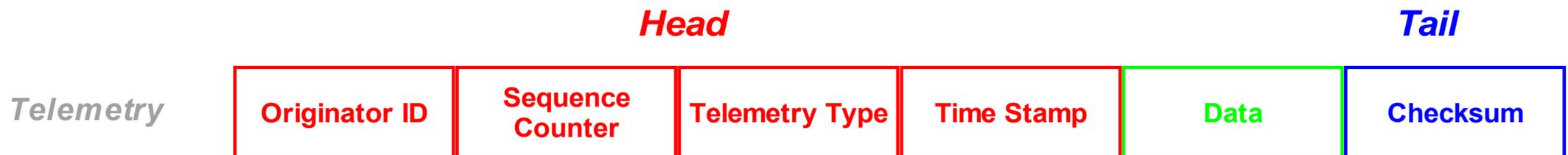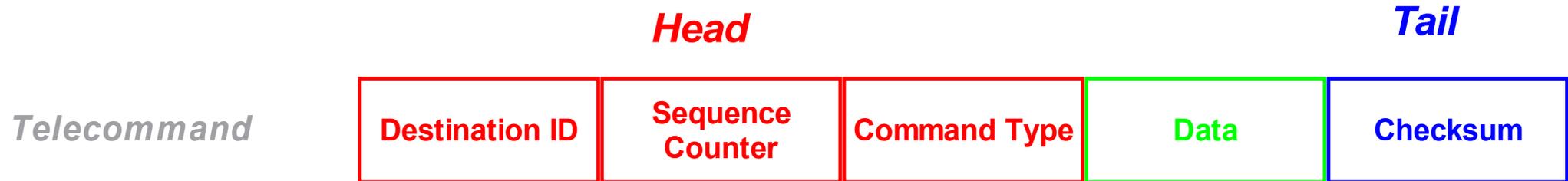
Functions

– **Telecommand verification**

– **Housekeeping data collection**

– **Event reporting**

– **Memory read/write**

– **Function activation/deactivation**

– **Time synchronisation**

– **Command time line**

– **Parameter monitoring**

– **Telemetry storage**

TERMA

Telecommand Verification

Telecommand Verification Service

– Success/failure of telecommand execution
– Error code
– Telecommand identification

Telemetry
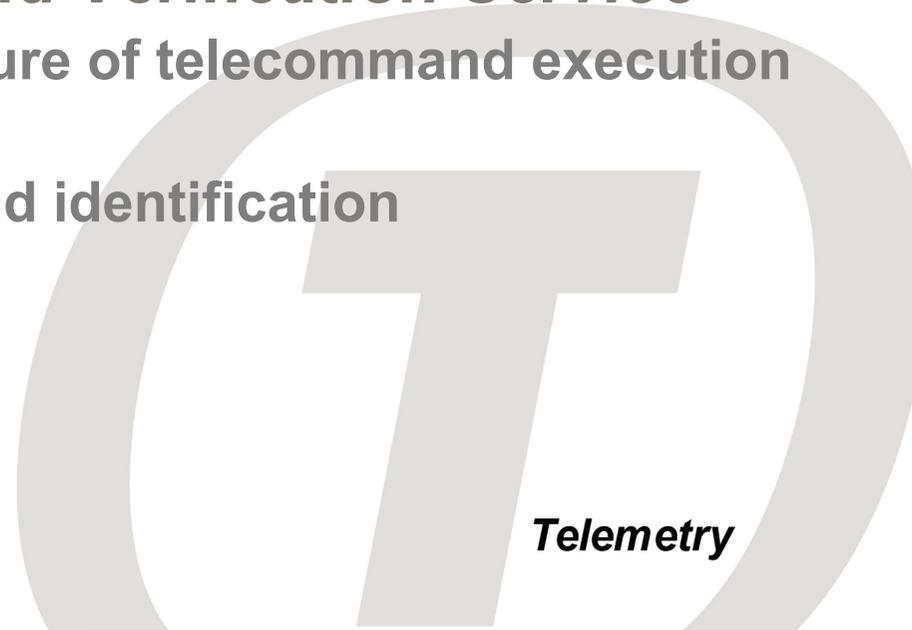
Acceptance/Completion

Telecommand Packet ID	Packet Source Control	Code	Parameters

Progress

Telecommand Packet ID	Packet Source Control	Step Number	Code	Parameters

Housekeeping Data Collection

TERMA

Housekeeping & Diagnostics Data Reporting

- Periodic reading of parameter values
- Reporting of temporally coherent values
- Typical period: 60 seconds
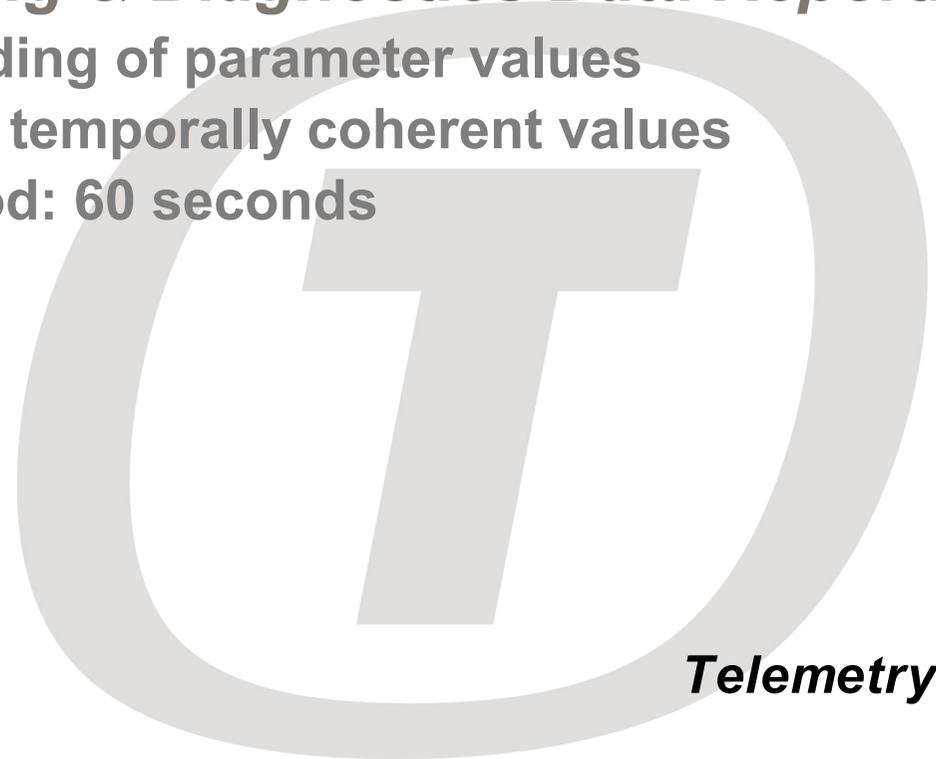
Telemetry

Housekeeping Report

SID	Parameters

Event Reporting

Event Reporting

- Nominal events
- Anomalies/errors

Telemetry

Event Report

RID	Parameters

Memory Read/Write

Memory Management
- **Reading/writing/verification**
- **Software updates (patching)**
- **Debugging/diagnostics**

	Telecommand			
Load	Memory ID	N	Start Address	Data

	Telemetry			
Dump	Memory ID	N	Start Address	Data

Telecommand

Dump	Memory ID	N	Start Address	Length

Checksum	Memory ID	N	Start Address	Length

Telemetry

Checksum	Memory ID	N	Start Address	Length	Checksum

Function Activation/Deactivation

Function Management

– Activation/deactivation of functions, modes etc.
– Execution of activities
– Functions identified by ASCII-string

Telecommand

Activate Funtion	Function ID	Parameters
Deactivate Funtion	Function ID	
Perform Activity	Function ID	Activity ID	Parameters

Time Synchronisation

Time Reporting

– Generate time reports containing time stamp
– Report related to event on downlink
– Period based on required accuracy

Telemetry

Time Report

Satellite Time

Command Time Line

Onboard Scheduling
- **Time line of telecommands**
- **Executed when due**
- **Updated based on operational schedule/time line**

Telecommand

Telemetry

Insert Telecommand

N	Abs/Rel Time Tag	Telecommand Packet

...

Delete Telecommands

Range	Time Tag 1	Time Tag 2

Report Schedule

N	Abs/Rel Time Tag	Application Process ID	Sequence Count
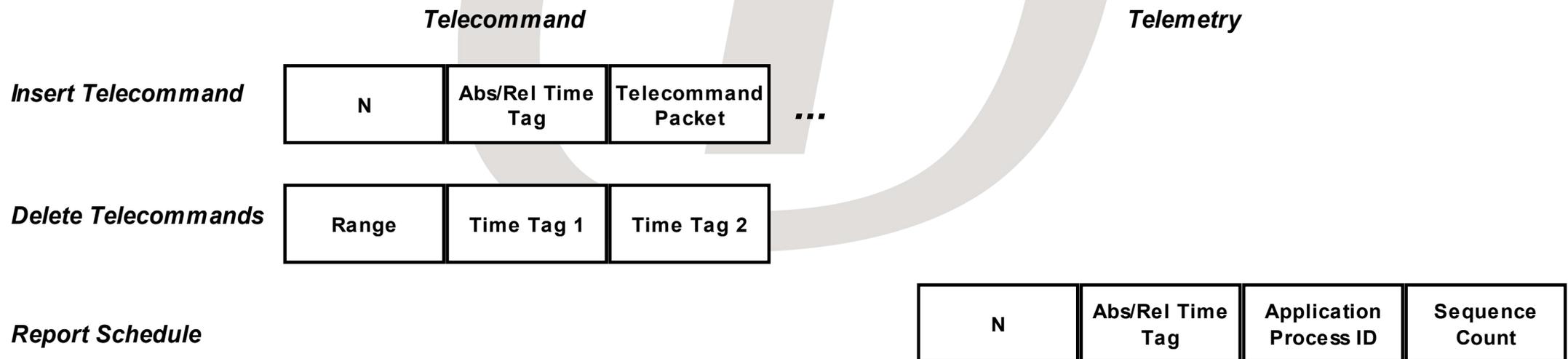
Parameter Monitoring

Onboard Monitoring

– **Periodic reading of parameter values**
– **Comparison against nominal range**
– **Report deviations**
– **Initiate error handling**
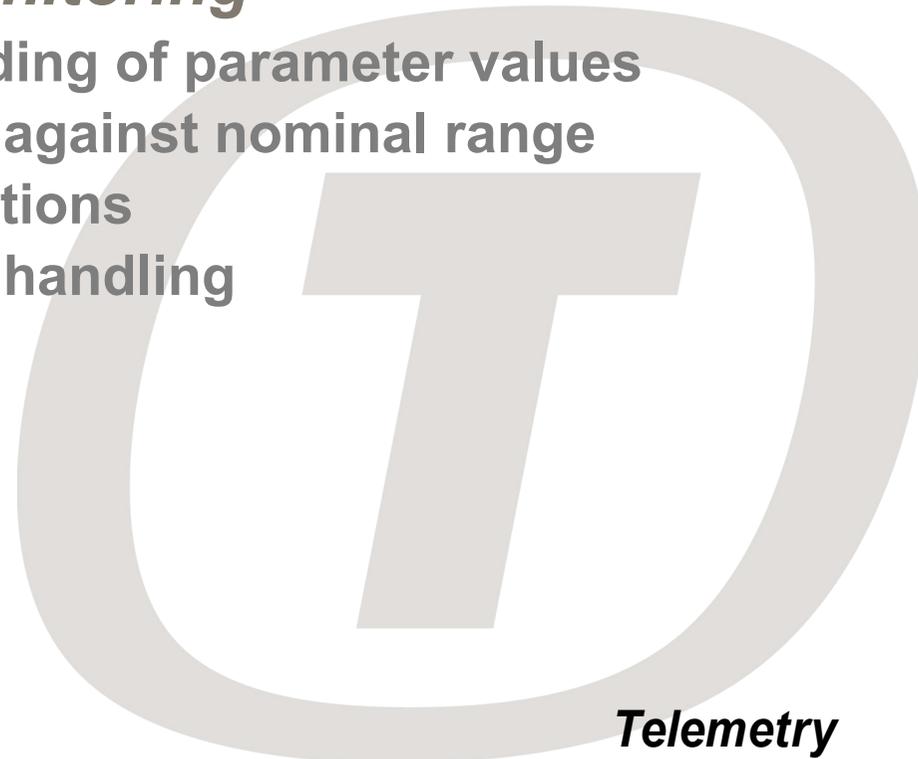
Telemetry

Out-of-Limit report

N	Parameter#	Parameter Value	Limit Crossed	Transition Time

...

Telemetry Storage

Onboard Storage & Retrieval

– Storage of telemetry
– Inserted in downlink during ground contact
– Separate stores for different telemetry types
– Prioritised read-out
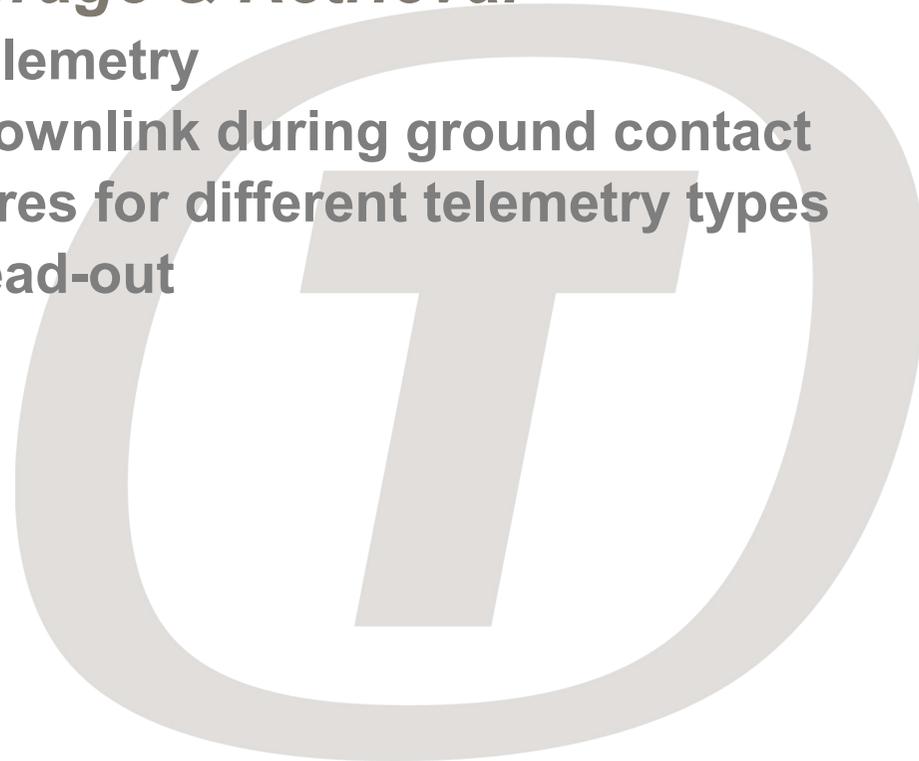
Exercise: Autonomy

Communication between satellite and control centre is possible 2 times 10 minutes per day.

The remaining time it must survive on its own.

What anomalies/event/situations should your satellite be able to handle autonomously?

Software Architecture

TERMA

Onboard Storage Administrator	Platform Manager	Telecommand Scheduler

Ground	Ground I/F	Packet Router	Payload	Payload

Attitude Control System	Power Conditioning & Distribution

Actuators & Sensors	PCDU Subsystem

Ørsted

TERMA

THE ØRSTED SATELLITE
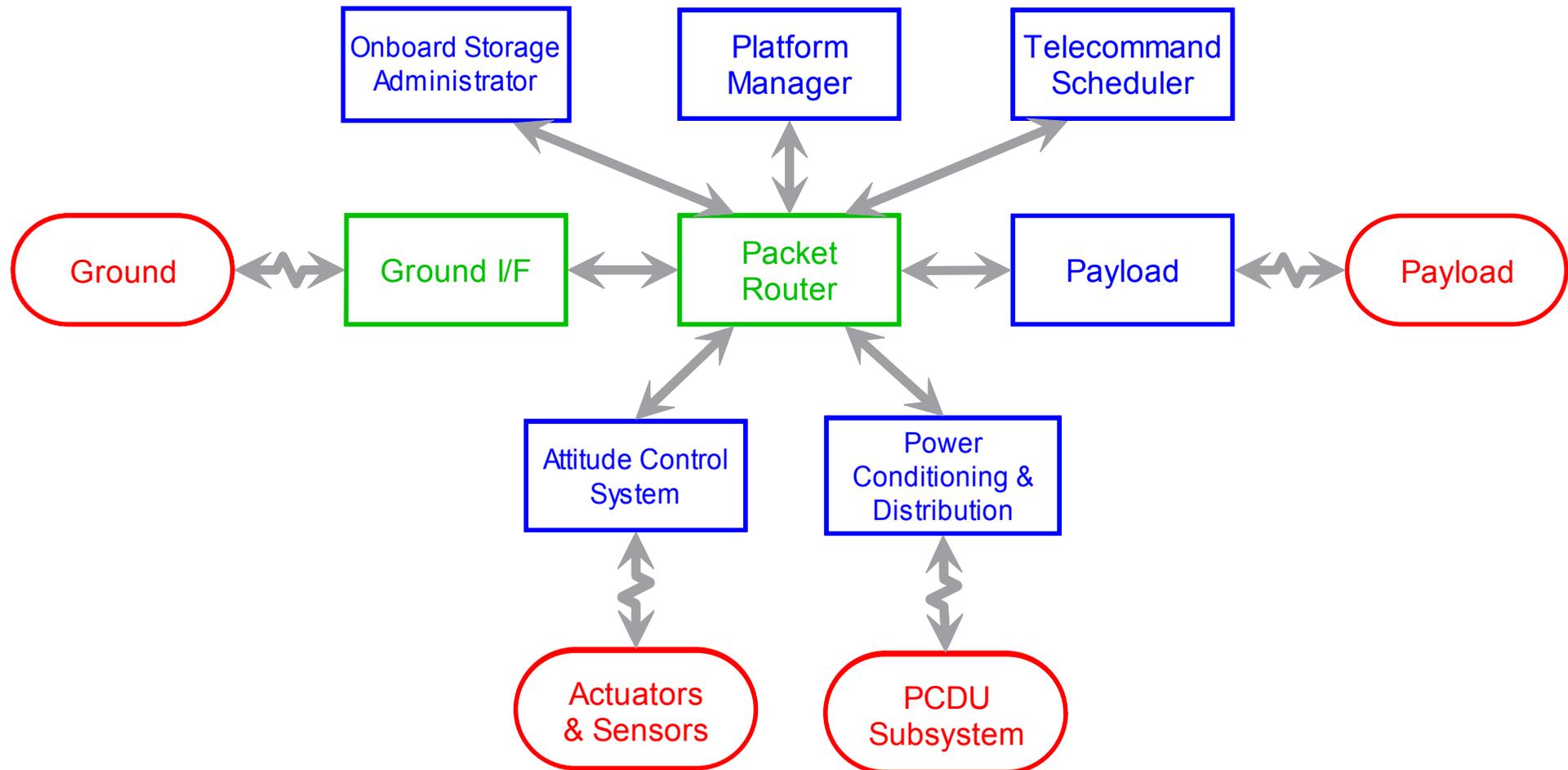
Ørsted onboard data handling

Hard Real-Time HOOD

Fomral RAISE specifications

Automatic code generation + manual programming

Ada 83

Scehdulability analysis: Deadline monotonic scheduling

In-Circuit emulator for software validation

Incremental development: Simulators ➢ prototypes ➢ final product

Ariane 501

– Error in Inertial Reference System

– 64-bit float ➢ 16-bit integer = *Overflow*

– Chain of errors:
  – Reuse from Ariane 4; No revalidation
  – No exception handling
  – Post-mortem dump ➢ Valid input for data handling software

Robustness

Software Robustness Engineering

- **Fault Prevention**
  - **Fault Analysis**
  - **Supporting Methods & Tools**
  - **Restricting Methods & Tools**
- **Fault Removal**
  - **Static Fault Removal**
  - **Dynamic Fault Removal**
- **Fault Tolerance**
  - **Error Detection**
  - **Error Recovery**
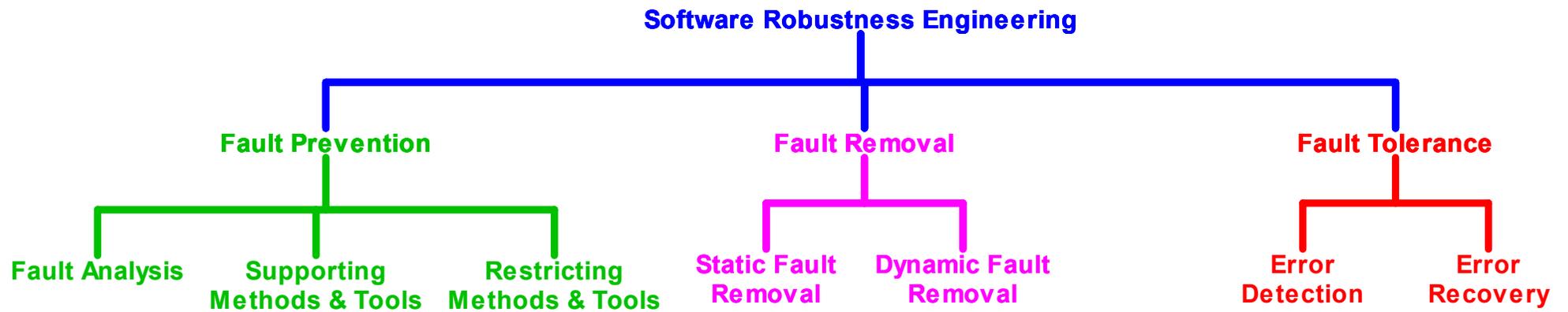
Pitfalls

Interfaces: Focus from day one

Bidets: Estimate and survey

Schedulability: Estimate and survey

Fault tolerance: Keep it simple, stupid! (KISS)

Verification & validation: Unit test, integration test, system test ...

Résumé

Embedded real-time software ➢ *Tasking kernel*

Real-time requirements ➢ *Schedulability analysis*

Fault tolerance ➢ *Fail-stop*

Numerous interfaces ➢ *Interface control documents*

Verification ➢ *Simulators & prototypes*

Keep it simple, stupid!