Operations

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Summary

■ **Overview**

■ **Operational concept**

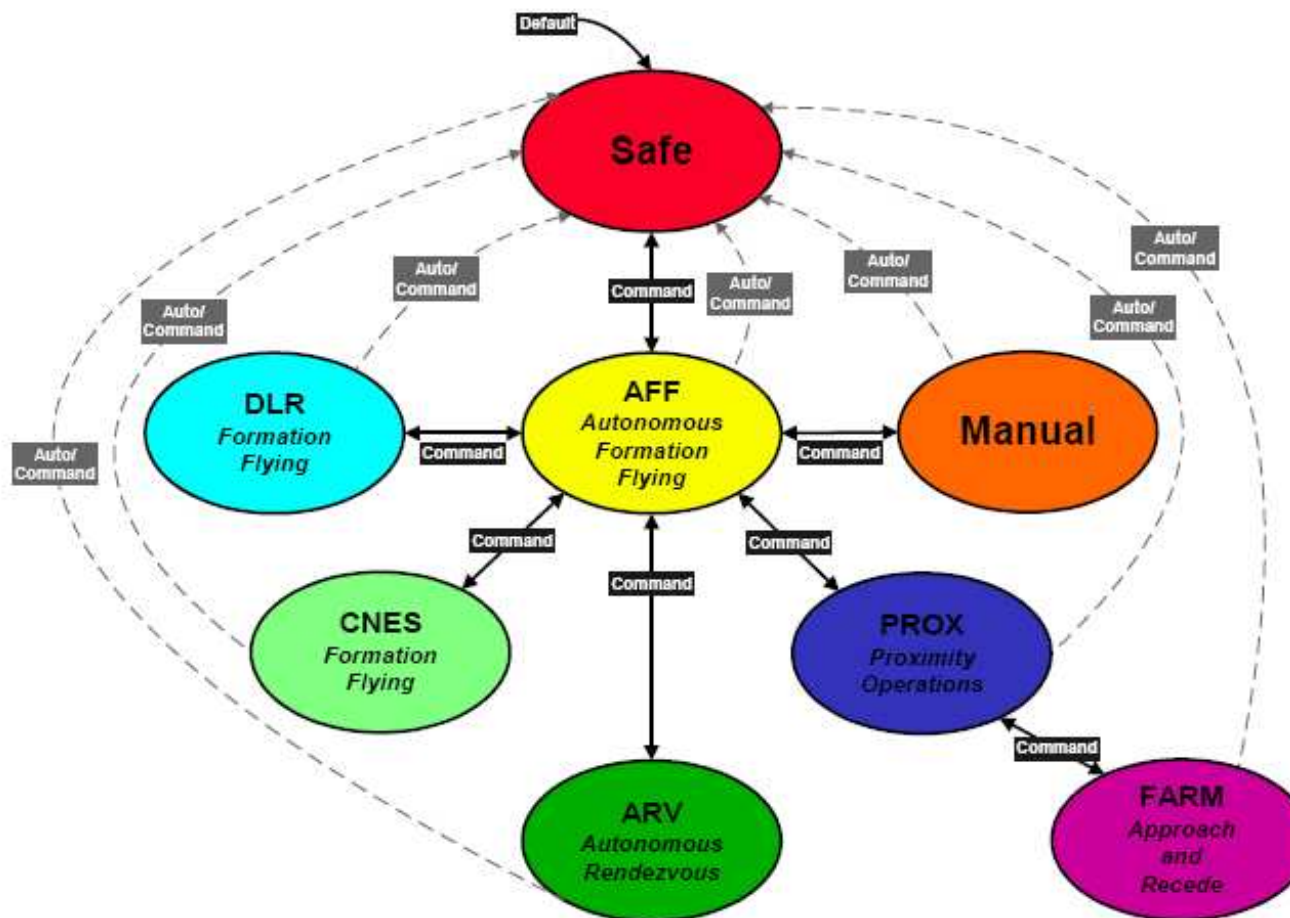 ◆ **Main principles, transition between experiments, telemetry**

■ **Programming**

  ◆ **XML scenario, validation loop, FMC-GNC tools**

■ **Monitoring**

  ◆ **Data retrieval, Ramses/Sphinx use, FMC-GNC use**

■ **Highlights**

PRISMA GNC modes

System architecture

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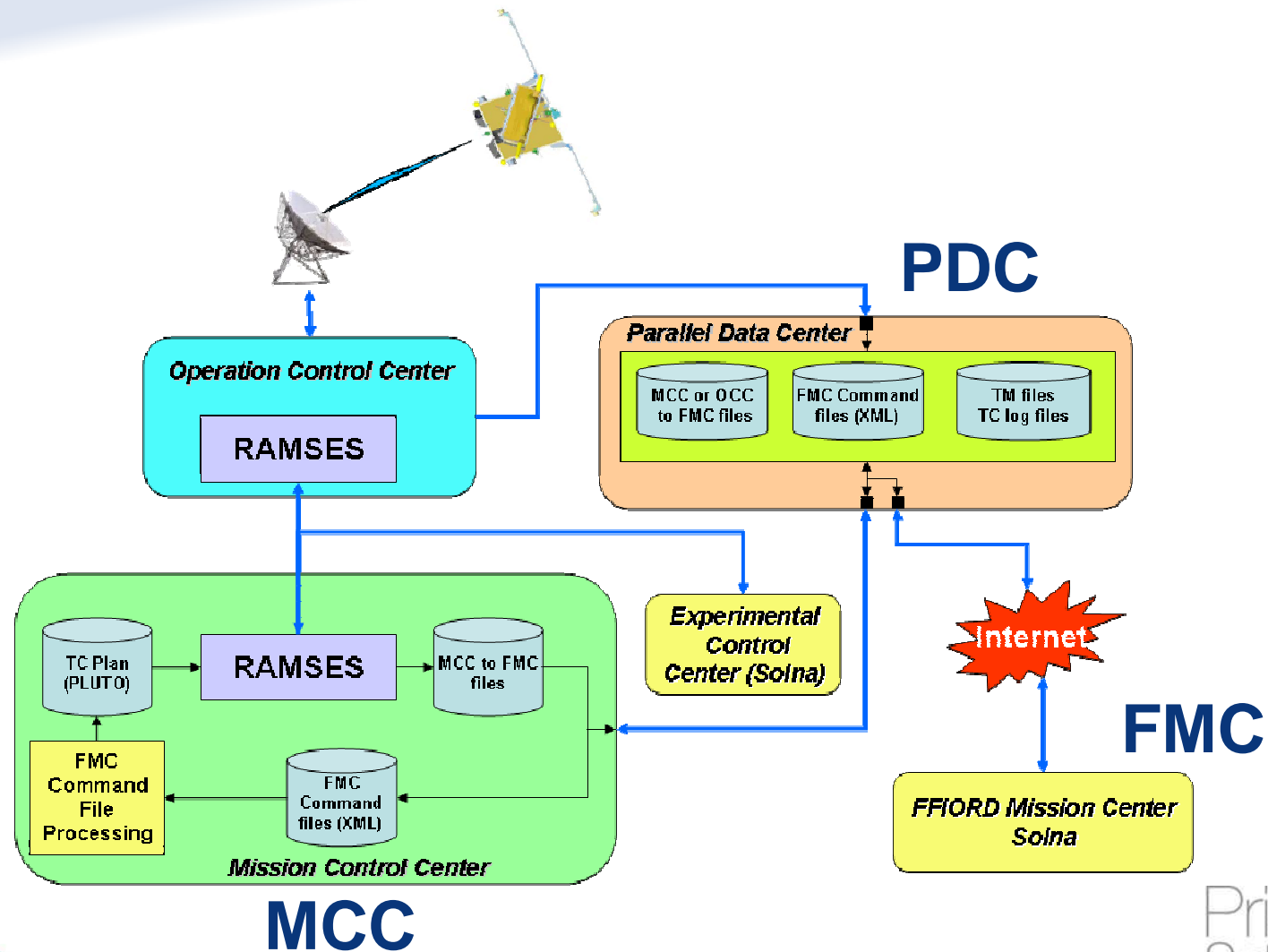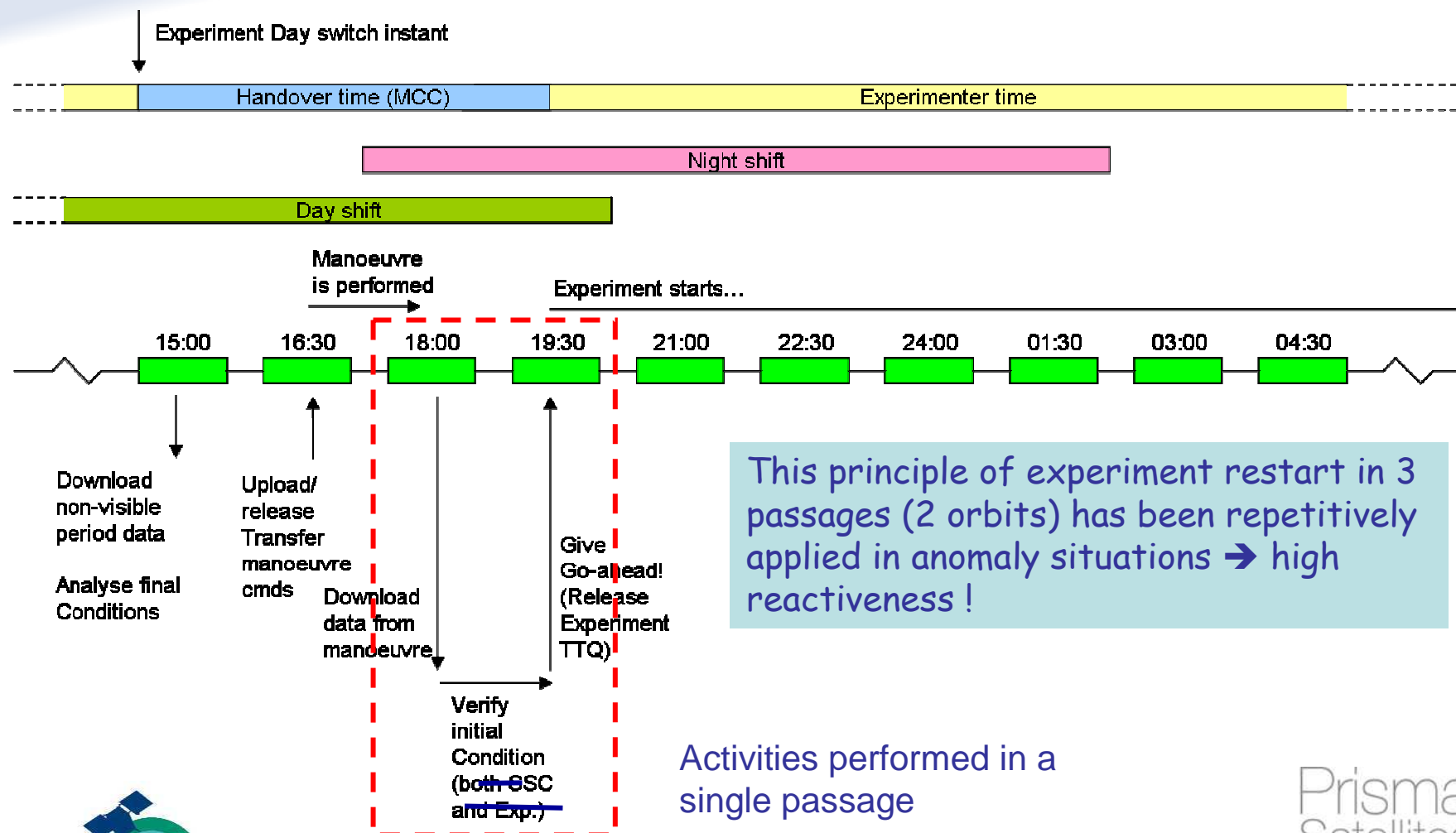　◆ **XML scenario, validation loop, FMC-GNC tools**

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Operational Principle

- **10-11 passages (1h40 period) from Kiruna station per day → no visibility before 13:00 UTC**

- **Typical FFIORD experiment duration is 24h. Experiments are autonomously executed until next scenario upload (absence of Go / NoGo capability).**

- **Typical day:**
  - **TM passages: from 14h until 07h UTC**
  - **Work hours : 11am until 02am next morning**
  - **Experiment duration : 24h (TBC) if initial conditions are verified**
  - **TM real time monitoring from MCC for « critical » opérations**
  - **Most of the time (99.9%) is spent in TM analysis from MCC (or from CNES CST).**

- **S band TM/TC with 1Mbit/s TM rate, CCSDS standard and PUS partially implemented. Nominal use: Time Tagged TC**

Experiment hand-over

This principle of experiment restart in 3 passages (2 orbits) has been repetitively applied in anomaly situations ➔ high reactiveness !

Activities performed in a single passage

Telemetry and operational principle
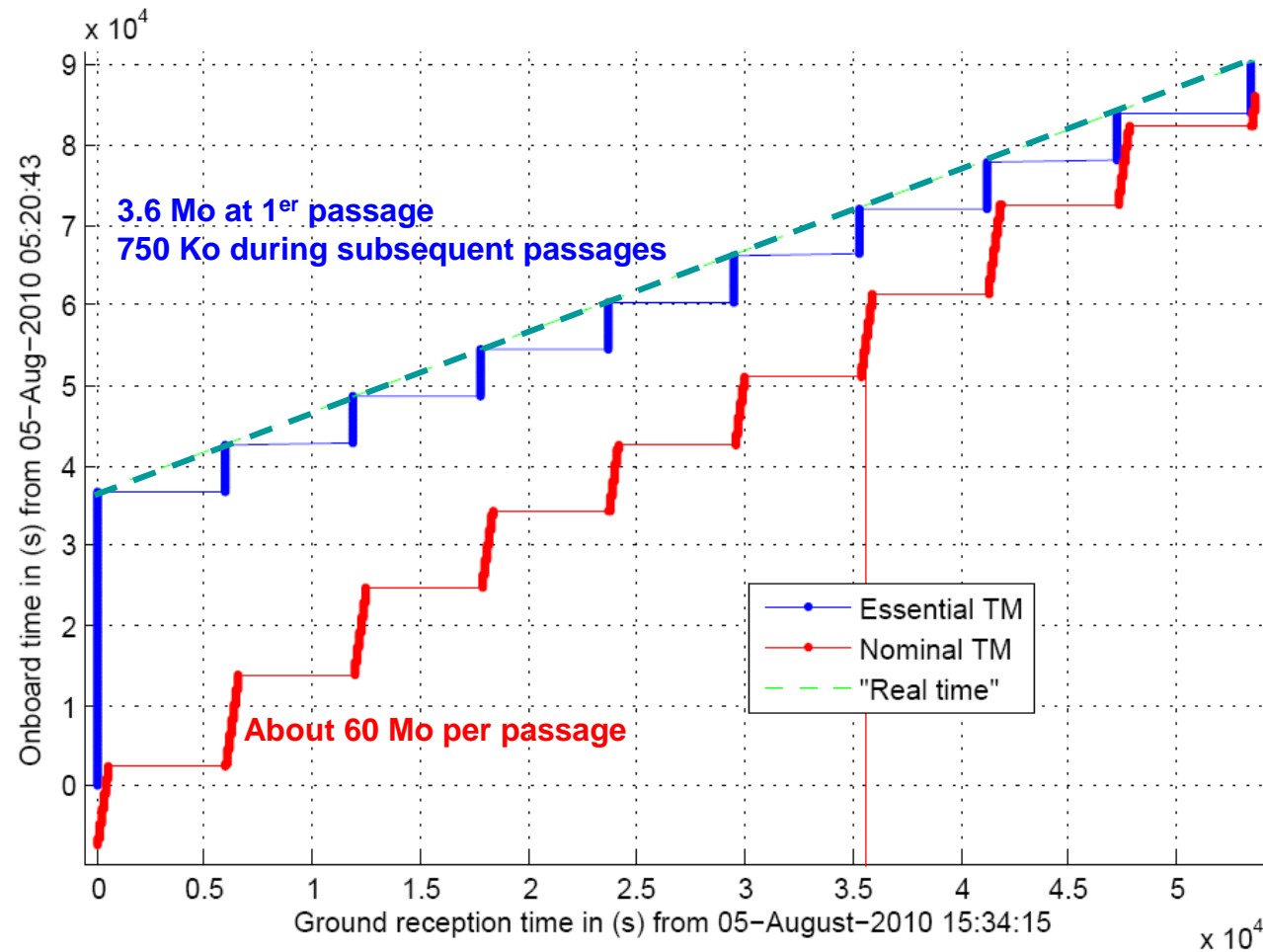
3 classes of TM :

■ **Nominal telemetry : mass memory dump** (VC1) **where are recorded all TM defined by the current TM mode.**

  ◆ Available after a delay that is progressively reduced (~10h at the 1er passage, 1h40 for the last ones)

■ **Essential telemetry: sub sampling of main nominal TM parameters at 1/60Hz** (VC1). **Useful for real time operations.**

  ◆ All essential TM is available at each passage : the oldest data is 1h40 late in all passages except the first one of the day (~10 h late)

■ **Real time telemetry** (VC0) **: data downloaded only during passages at the rate defined by the nominal TM.**

  ◆ Available in real-time during the passages

Telemetry and operational principle

■ TM reception chronogram during a single day :

TM on board time versus TM reception date

3.6 Mo at 1er passage
750 Ko during subsequent passages

About 60 Mo per passage

Legend:
- Essential TM
- Nominal TM
- "Real time"

Y-axis: Onboard time in (s) from 05-Aug-2010 05:20:43
X-axis: Ground reception time in (s) from 05-August-2010 15:34:15

FFIORD Seminar – March 7th, 2012

Main operational tools

- **<u>PDC</u>: Parallel Data Center : server accessible as a internet website, that contains all PRISMA data** (TM, TC, procedures, TLE…)

- **<u>RAMSES</u> : Rocket And Multi Satellites EGSE System : Control / Mission Center (Solna)**
  - **Developped by SSC**
  - **Test version on some FFIORD mobile computers at MCC**

- **<u>FMC-GNC</u> : FFIORD Mission Center GNC**
  - **Set of Matlab tools (DCT/SB/PS) totally portable**
  - **Deployed on all FFIORD mobile PC (Unix use is possible)**

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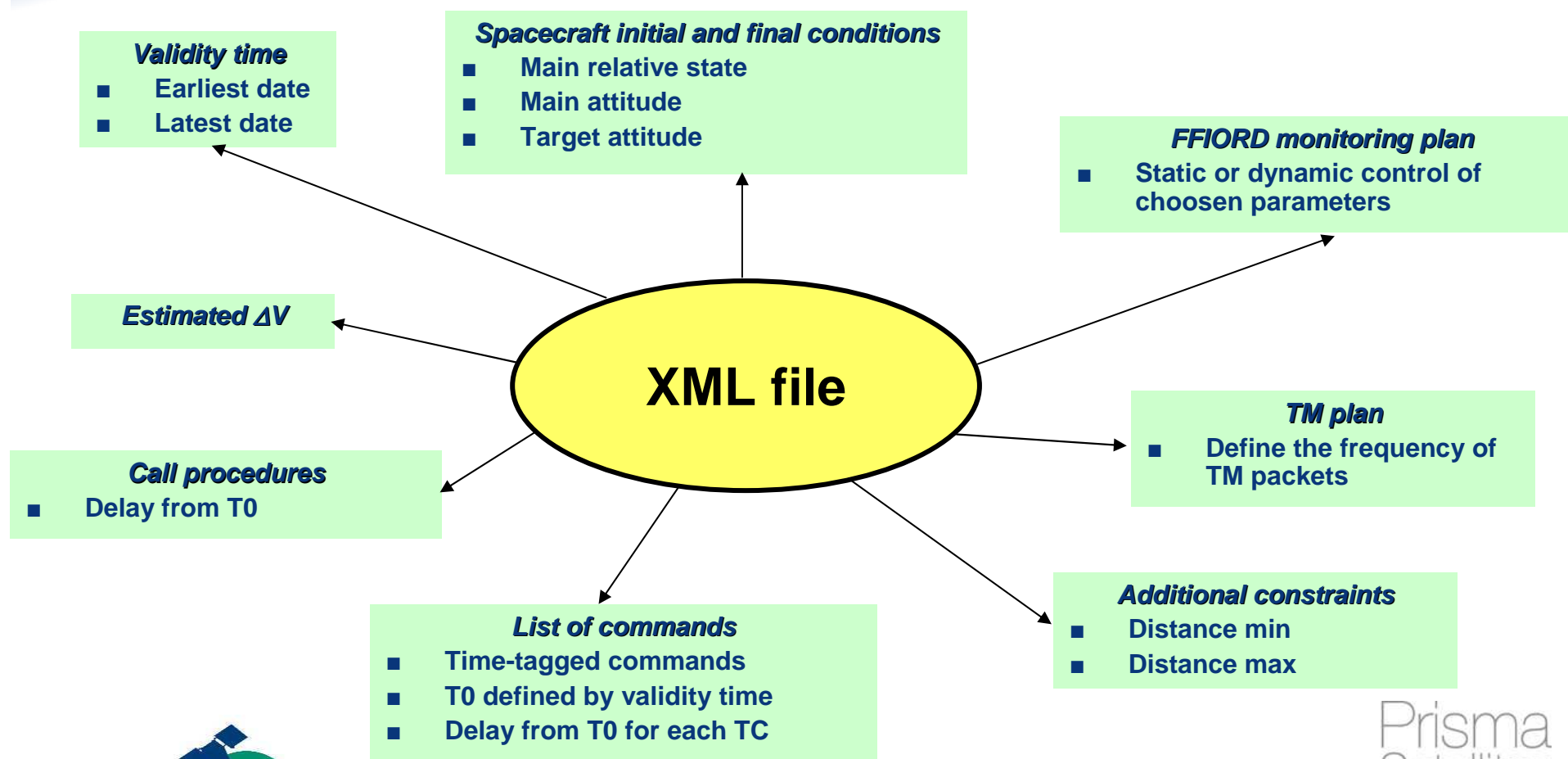 ◆ **XML scenario, validation loop, FMC-GNC tools**

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PRISMA – FFIORD programming

XML language and high level description

Validity time
- Earliest date
- Latest date

Spacecraft initial and final conditions
- Main relative state
- Main attitude
- Target attitude

FFIORD monitoring plan
- Static or dynamic control of choosen parameters

Estimated ΔV

XML file

TM plan
- Define the frequency of TM packets

Call procedures
- Delay from T0

List of commands
- Time-tagged commands
- T0 defined by validity time
- Delay from T0 for each TC

Additional constraints
- Distance min
- Distance max

Programming loop

Program edition
    24h scenario with full autonomy (mode change, FDIR)
    From 50 to 1800 TC according to complexity

FMC-GNC

program validation
    → elementary validation + XML translation
    → Simulink simulation (incl. Monte Carlo)

program sent to PDC and automatic translation in Pluto

Simulation on GNCViewer by SSC for cross-validation

FMC-GNC

GNCViewer results retrieval for post processing, display and validation / approval

Nominal: To be sent 1 to 2 weeks before experiment t0.
    Final tuning and formal acceptance a few days before t0.

Programming loop

Program edition

```
function struct_FFIORD_prog =
    prog_FC_CMD_CNS_6004_OFF_FFRF_TARGET()

%% Automatic initialization of the program
prog_autoInitialization;

%% Validity_time
prog_setDates('2009/08/31 12:00:00','2019/08/31
    12:00:00',50);

%% Program ID
prog_setProgramId('FC-CMD-CNS-
    6004','OFF_FFRF_TARGET','V1.0');

%% TLE param
TLE_param = prog_metaTLE('TARGET_20110221.TLE');

%% Command
prog_setTcFfrfWMODE(0,'TARGET','init');

prog_setCommand(15,'TC_tfsFappCmd',[7,0]);

%% LQ tuning
prog_metaControlProx100200300(70, TLE_param,zeros(1,5));

%% Automatic termination of the program
prog_autoTermination;
```
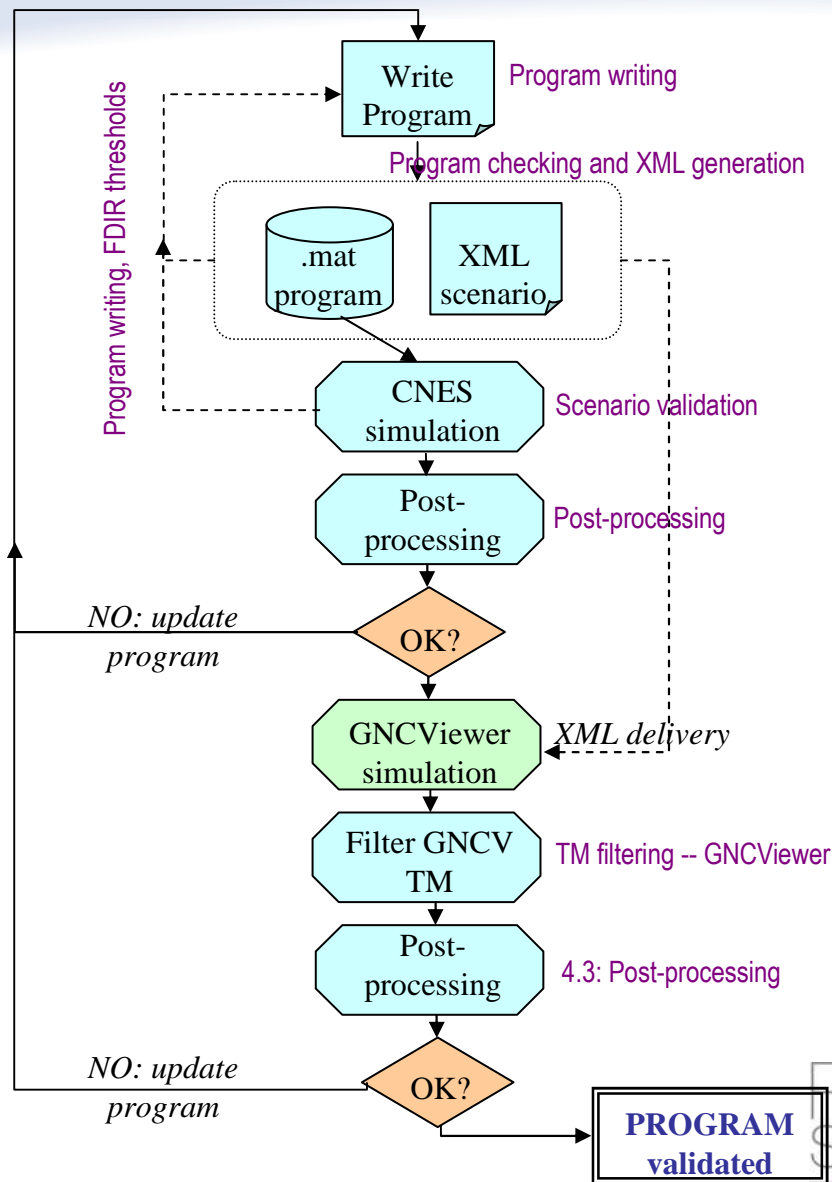
FFIORD programs represent :
~ 40 program files / 10500 TC (nominal)
  23 program files / ??? TC (extended)

Program writing, FDIR thresholds

Write Program — Program writing

Program checking and XML generation

.mat program   XML scenario

CNES simulation — Scenario validation

Post-processing — Post-processing

OK?

NO: update program

GNCViewer simulation — *XML delivery*

Filter GNCV TM — TM filtering -- GNCViewer

Post-processing — 4.3: Post-processing

OK?

NO: update program

PROGRAM validated

Programing – XML format display

■ **Possibility to display the XML program with a Web Browser → very useful**

■ **Generation of a program summary in XML format with FMC-GNC:**
- ◆ **Header**
- ◆ **List of commands with relative an absolute date (calendar) and related comments**

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2 monitoring levels

■ **Close monitoring by the GNC FFIORD team:**

- ◆ Real time monitoring (only during passages) for critical operations
- ◆ Monitoring of the following parameters (essential TM)
  - FFRF health status (for the first activations)
  - RF signal acquisition (start of each experiment)
  - Navigation function status :
    – Mode depending on sensor state
    – estimated position compared to GPS
  - FFIORD mode handler state (GNC mode, possible anomalies)
  - Actual trajectory compared to expected trajectory
  - DeltaV usage

> - FDIR is achieved by the on-board system at different levels (PRISMA platform, PRISMA GNC, FFIORD).
> - No ground alarms at FFIORD level

■ **Telemetry analysis :**

- ◆ *FFIORD functional behavior*
- ◆ *Performance analysis*
- ◆ *Every scenario is analyzed separately*

> **Represents most of the work…**
> Possible actions:
> - Modification of subsequent scenarii to improve tuning (RF nav)
> - Send a TC to modify some parameters at the next passage

Data access

■ **Real time monitoring**

♦ **Only from MCC (Stockholm) via RAMSES tools**

■ **Off line access via Internet (Web navigator)**

♦ **possible from MCC (Stockholm) or any network (CNES CST, hotel, home, etc ..) to process all TM « a posteriori » and analyze FFIORD behavior**

♦ **Utilization of FMC-GNC : or** utilization of other specific tools (FMC-SIF)

♦ **Latency**

• *Essential TM is available on PDC <2 min after passage start.*

• *TM nominal / real time is available on PDC < 4 min after the passage end.*

* A status synthesis with plot of the main parameters is automatically produced at each passage in HTML format ➔ allows remote quick monitoring !

Real time monitoring – RAMSES overview

■ **RAMSES : Rocket And Multi Satellites EGSE System**

♦ **Set of tools for TC management, TM retrieval, archiving, data extraction, display etc..**

♦ **PRISMA experimenters use a PC with a subset of RAMSES tools**

■ **Sphinx: data extraction, TM calibration and display, possibility to design customized IHMs**

Sphinx FFIORD page

Monitoring – FMC-GNC overview
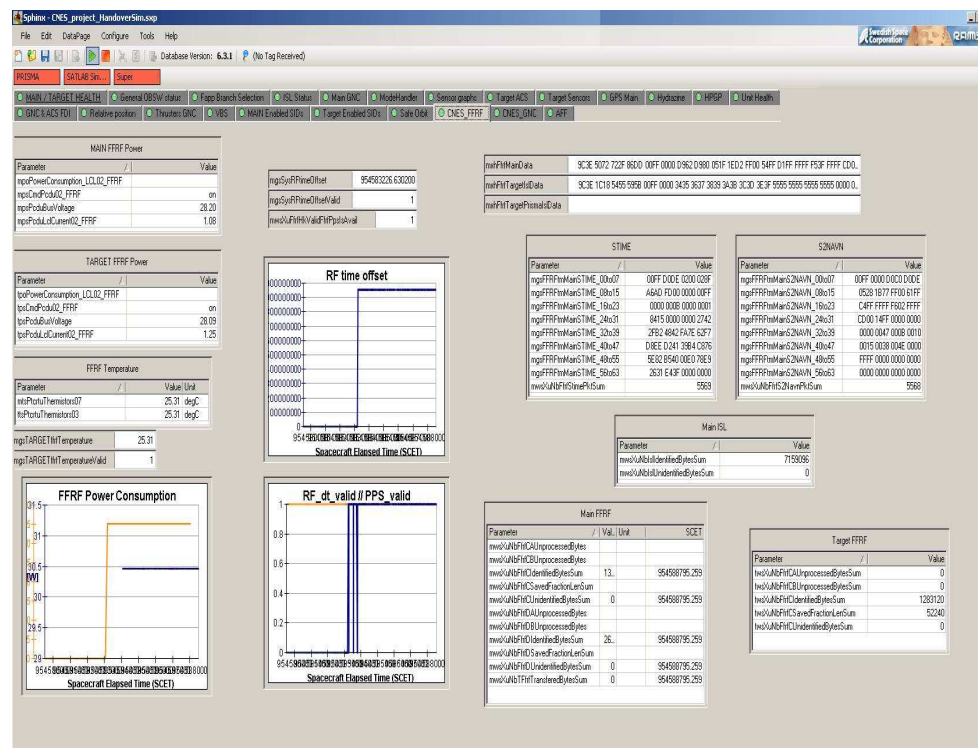
- **FMC-GNC is a set of GNC functions that can be used in the Matlab/Simulink environment**

- **FMC-GNC offers the following services:**
  - **Program generation:** program edition, XML format generation, complete validation before upload on PDC

  - **TM extraction / import :** TM extraction from archive files or import of FMC-SIF extracted TM

  - **TM Post-processing :** data time synchronization, data comparison, error signal generation, performance characterization…

  - **TM display :** simple display of TM raw parameters, or advanced display after post-processing

  - **Test report generation :** automatic generation of test reports (Word) providing a synthesis of the GNC FFIORD behavior and related performances

Un unique fichier Matlab par jour contenant tous les paramètres TM (.mat : ~50Mo)

→ Très pratique et efficace

FMC-GNC services can be called via the IHM or from Matlab prompt

Data volume:
~2400 paramters extracted for FFIORD → 470 Mbytes / day
< 10 min to extract all TM from a single day *(quasi instantaneous upload)*

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Highlights (1)

- **Great operational success !**
  - Even though the demonstration program was highly ambitious, the main activities allocation was respected and no anomaly led to the postponement or cancellation of experiments (➜ on-board system autonomy and agility + operations infrastructure and organization)

- **Easy data access:**
  - **Remote and quick access to all project data via Internet**
    - ➜ **particularly useful for TM retrieval**
  - **Access to satellites status via smartphone (but no TC upload yet !)**

- **Operational flexibility and reactiveness**
  - **Ability to handle late delivery of mission programs and procedures**
  - **Quick recovery after anomaly (demonstrated several times)**

- **Matlab/Simulink efficiency as an integrated tool for ground activities**
  - **From design studies to software development, program editing & validation, TM data extraction and processing**

Highlights (2)

Reactiveness illustration

(1) 00:50 → a VBS problem triggers a transition in AFF mode then Safe mode since Mango is very close from Tango (30 m)

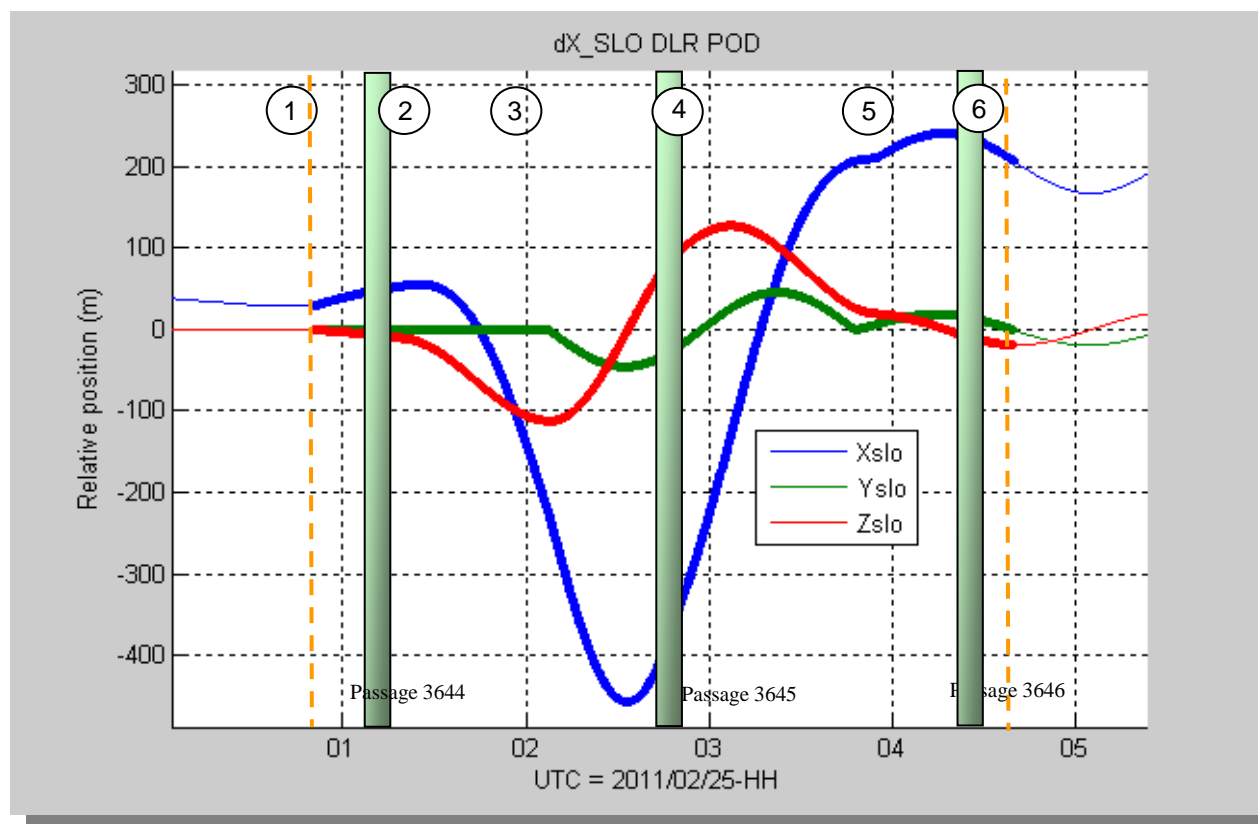(2) Anomaly detected during passage 3644, Mango is drifting 500 m away from Tango

(3) Décision to restart the task scenario and preparation of a transition plan

(4) Transition plan and task upload during passage 3645

(5) Transition plan manoeuver execution

(6) Relative state verification during passage 3646 – Task scenario restarts at 04:39

Back in track in less than 4 hours after anomaly and collision avoidance !!