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Innovative Operational Concepts & Organization to meet the operation challenges of the Kinéis constellation

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Abstract

Kinéis is a French company that operates a constellation of 25 nanosatellites which guarantees precise connectivity and tracking of any object anywhere on the planet. The satellites are distributed on 5 orbital planes (5 per plane).

All 25 satellites have now been launched from New Zealand by Rocket Lab 5 by 5 on 5 dedicated launches (between June 2024 and March 2025).

This paper deals with CNES and Kinéis collaboration to operate Kinéis constellation. It describes the different operational concepts (for Launch and Early Orbit Phase (LEOP), post-launch maneuvers phase, routine/station keeping phase and collision avoidance operations) and the associated organization to manage the constellation.

The design of the mission with different payloads (Automatic Identification System (AIS) for ships monitoring and Internet of Things (IoT) connectivity – Argos-next generation), as well as different orbital planes (hot/cold) implies specific constraints and CONOPS to manage at satellite or orbital plane level. As part of the overall Kinéis mission, CNES is in charge of the command-control center and associated operations during the constellation deployment and first months of routine operations.

The different components in Kinéis system are the following ones:

- 25 nanosatellites (30kg class) with a lifespan of 8 years, using an electric propulsion system
- 20 dedicated ground stations installed by Kinéis
- A mission center with two functions: to route the data between ground-stations and other components and to manage the payloads
- A command-control center to manage the satellites' platform (via the mission center)
- A service center to manage the customer interface

The system has an interface to European Union Space Surveillance and Tracking (EUSST) for collision avoidance.

There are between 70 and 80 ground station/satellite contacts per satellite per day (more than 1800 passes daily), so everything needs to be automated. The routine operational concepts are based on this automation:

- No control center activity linked to specific ground-station flybys
- Automatic visibility allocation for satellite ground-station pass scheduling
- Tx/Rx scheduling
- Station keeping maneuvers computation
- Collision avoidance management

This operational complexity involves a close coordination between all components. This close coordination and the high level of automation achieved have enabled the teams to face unplanned events during the deployment of the constellation and to focus on anomalies and not on "standard" operations. Dealing with 25 satellites in parallel proved to be a challenge when the operations are performed by a reduced team and optimized means.

Keywords: constellation, automation, electric propulsion, HR optimization

Acronyms/Abbreviations

AIS	Automatic Identification System
CNES	French National Space Agency
EUSST	European Union Space Surveillance and Tracking
FD	Flight Director
FDIR	Failure Detection Isolation and Recovery
FDS	Flight Dynamics System
FOE	Flight Operations Engineer
FSW	Flight Software
GCS	Ground Control Segment
GOT	Ground Operations Team
GRS	Ground Remote Station
HKTM	Housekeeping Telemetry (-R for Recorded and –P for Passage)
IoT	Internet of Things
IOV	In Orbit Validation
LEOP	Launch and Early Orbit Phase
MCS	Mission Control Center
OBC	On-Board Computer
OCG	Operational Coordination Group
PLTM	Payload Telemetry
Rx	Receiver
SATSIM	Satellite Simulator
SC	Service Center
SLA	Service Level Agreement
TC	Telecommand
TOMS	Training, Operations and Maintenance Simulator
TM	Telemetry
Tx	Transmitter

1. Introduction

The Kinéis constellation is now deployed at an altitude of 650km. The service has been partially opened to customers beginning of February 2025 (with satellites of plane 1) and will be fully available mid-2025.

Kinéis and CNES have been working on this project since 2019. The development and system validation phases have been optimized to reach the launch target in 2024.

This paper will browse these subjects:

- A presentation of Kinéis system:
  - Kinéis missions (AIS and IoT)
  - Kinéis components including the CNES command-control center
- The overall organization and the system validation
- The operational concepts for each phase
- A first feedback on Kinéis operations.

2. Kinéis system

In figure 1 is an overall view of Kinéis system:

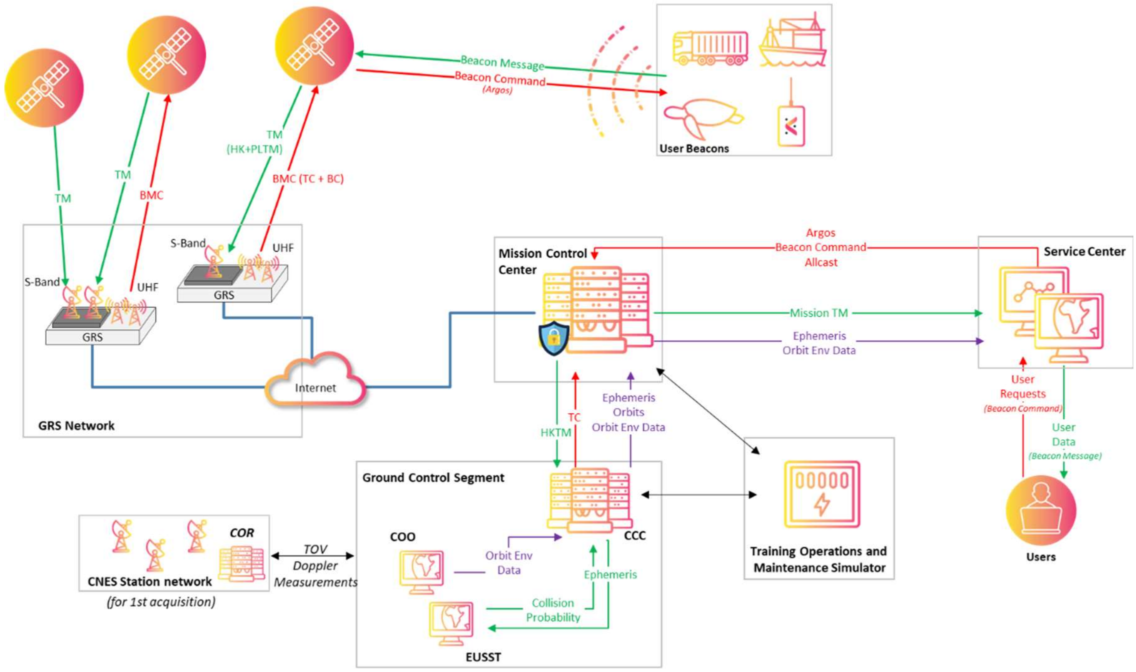

Fig. 1. Kinéis overall system architecture

2.1 Kinéis flight segment and missions (AIS and IoT)

Each satellite is made of:

- A generic platform manufactured by HEMERIA
- An IoT payload (used also for the platform TC reception) manufactured by Thales Alenia Space

Depending on configuration:

- Either an AIS payload developed by Thales Alenia Space
- Or a dummy payload.

There are two missions (2 instruments):

- IoT: The IoT mission is an extension of the existing Argos 4 missions. Argos is a global satellite-based location and data collection system dedicated to studying and protecting our planet's environment. Kinéis connectivity enables any object to be located across the world, and to transmit data collected from its measurement sensors. Each device transmits messages to the nearest IoT instruments on-board satellites that pass overhead. A network of ground stations is then used to immediately retrieve satellite Mission Telemetry and forward it to Kinéis processing centers.

  This new generation includes 2-ways connectivity in both directions. The number of satellites and the number of daily passes by satellite enable to collect every information from transceivers in about 15 minutes (transceiver-to-satellite-to-ground-station-to-service center).
- AIS: Reception and processing of messages transmitted by maritime mobile or fixed AIS stations.

2.2 Kinéis Ground Segment

The ground segment is composed of:

- Ground Remote Stations (GRS) (x20) in charge of communicating with the satellites. Each station is equipped with 1 to 4 antennas in order to collect simultaneously up to 4 Kinéis S-band TMs. With this large ground-station network, the satellites are in visibility around 45% of the time.
- A Mission Control Center (MCS): It is the hub of the ground segment, in charge mainly of:
  - Centralizing all TC requests
  - Routing the TM flows to the different centers
  - Monitoring and controlling the payloads
  - Computing ground station visibilities and scheduling the satellite passes
  - Tasking and monitoring the ground stations
  - Interfacing with the security gateway for TC authentication and for TM/TC flows authentication/encryption
- A Ground Control Segment (GCS): In charge mainly of:
  - Monitoring and controlling the platform
  - Maneuver’s computation
  - Orbit determination and propagation
  - Orbital events computation
  - Collision risk management
- A Service Center (SC): In charge mainly of:
  - Managing IoT and AIS device messages and commands, in interface with the end-users
  - Localizing IoT user devices
- Different simulation facilities with different representativeness levels depending on the validation needs.

3. The overall organization and system validation

3.1 System validation before the 1st launch

There were 3 validation phases that overlapped depending on the topics:

- compatibility tests to assess interfaces between components,
- technical qualification to assess the technical functioning of the system chains. This qualification also included operability tests to assess the control & command of satellites from the ground control system,
- operational qualification to assess its usage in operational conditions (with the trained teams, with the target timeline in the target environment).

The first tests were mono-satellite and the validation planning increased progressively in complexity. We performed different tests for the different deployment phases (LEOP, post-launch maneuvers, routine, maneuvers) including the transitions between phases. We also validated the most demanding operation configuration with the last LEOP in parallel of 1 plane in post-launch maneuvers and 3 planes in routine, to assess the capacity of the system to handle the automated operations of the 25 satellites in parallel.

The FSW was developed in parallel with the first validation tests so we needed to manage a global planning consistency including the FSW versions releases, simulator availabilities, system tests (operability, LEOP, routine). A weekly Obeya meeting (visual management) took place to coordinate all components' plannings and all actors and to reconfigure in case of project hazards (and there were some). To face those hazards that impacted the planning (but not the deadline), the team needed permanent agility: some tests were merged to optimize the planning, some tests were replayed during other tests when needed. The scopes of each test was reviewed before the test and the global planning adapted.

The planning was also optimized to focus on necessary tests and avoid nice-to-have tests. Some tests could not be performed during the system validation phase and the operations had to be performed directly during IOV (with everything that could be assessed on the simulator done beforehand). But the main functions and the overall operability of the constellation was ground-qualified before the 1st launch.

To manage the project resources and the HRs in particular, there were pauses (2 weeks in general) between system tests to take time to analyze the results and apply corrections when needed. Vacation periods have also been planned for HRs to recover and not be already exhausted for the 1st launch. This kind of project is a long-term marathon and we need to take good care of operational people.

3.2 Project staffing

Kinéis team is in charge of designing the system and the procurement of the system components. CNES is in charge of developing and operating the GCS including the Flight Dynamics System (FDS). CNES is also in charge of organizing the GCS operations for the different phases and defining the operational concepts. Kinéis is in charge of the development and operation of all other ground components and the procurement of the flight segment (platform and payloads).

A close coordination is performed between Kinéis flight directors (4 people) and the CNES mission managers (2 people).

A sufficient staffing was necessary to ensure the project continuity and to manage people workload and pause needs (vacation…).

The most critical operations have been performed during the LEOPs and they requested the largest number of people. The control center room and all HRs have been sized to ensure the succession of 5 LEOPs operations with backup people. Each LEOP concerned 5 satellites.

LEOPs were designed to last 48h at maximum. So teams were organized in 2 shifts, each handling 12 hours. On the GCS side, there were 1 flight operations engineer (FOE) per satellite, plus 1 FOE coordinator per shift. The coordination roles were designed to be able to handle the LEOP with 1 anomaly (2 flight directors and 2 mission managers). Other roles were designed to manage the different components.

A total of 40 people (including experts) per shift were in charge of conducting the LEOP's operations.

3.3 Operational organization starting at the 1st launch

The tight schedule implied to parallelize multiple activities during and between the different launches. The team was sized in order to:

- Have the capacity of parallelizing a new LEOP with post-launch maneuvers and with routine operations.
- Have the capacity of performing some additional system tests in parallel to post-launch maneuvers and routine operations (however no test in parallel to LEOP phase).
- Have the capacity of taking actions outside working days/hours ⇒ On-call team.

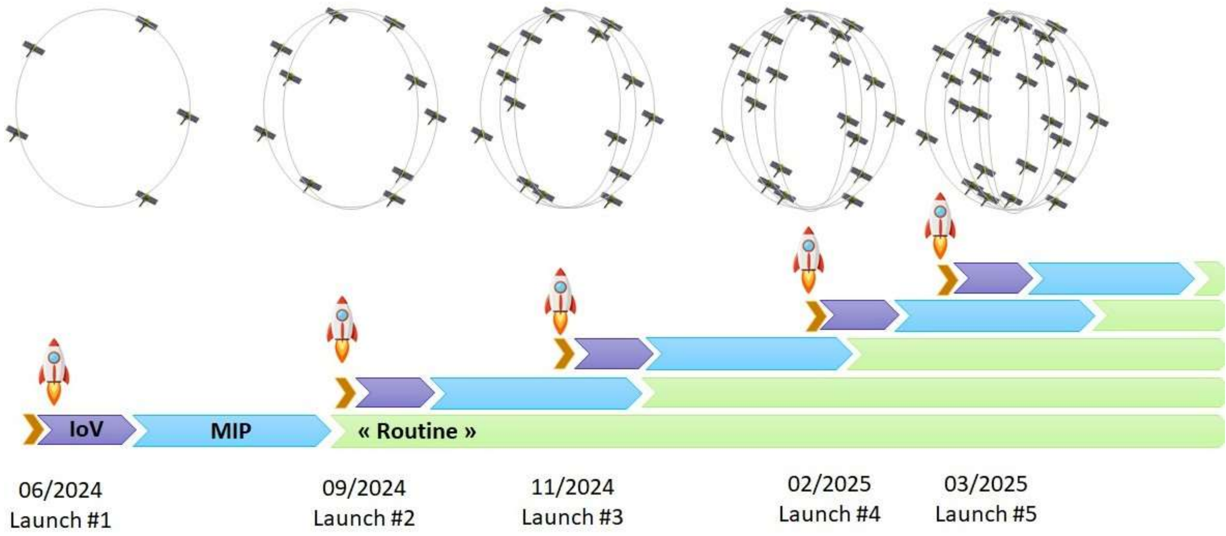

Fig. 2. Launch planning

So even if globally there is the capacity to parallelize, in case of conflict between the different activities, the main principles are:

- An overall coordination of the operations by one team to manage operations of different nature (IoV, routine, anomaly management...)
- Priority to LEOP phase and any other issue that could put in danger the constellation integrity. The worst scenario was to have to manage a LEOP phase with a collision risk for a satellite already in orbit. It happened during 2 of the 5 launches and the teams managed to handle the collision risk at a specific quiet moment during the LEOP
- Satellites are very autonomous (with Failure Detection Isolation and Recovery (FDIR) service implemented on-board) and, for instance, a satellite transition into SAFE mode is not considered critical, neither at satellite level nor at mission level and does not require the on-call team to take immediate actions. The recovery takes place during working days/hours.
- To minimize the staffing of on-call teams for 25 satellites, on-call team solicitation has been reduced as much as possible.
- In Orbit Validation (IOV) is done by the same team as the one in charge of routine activities. In case of conflict, IOV operations have been rescheduled later.
- As a general rule, the operations are prioritized taking into account (decreasing importance order):
    - Satellite safety
    - Impact on operation management (and capability to be handled in safe conditions)
    - Mission service interruption
    - Mission service commissioning.

The prioritization is performed at the coordination cell level between Kinéis and CNES, except long mission interruption that are discussed at steering committee level.

It is important to highlight that all these principles mean a potential degraded mission service during the first year. The goal is to achieve the expected Service Level Agreement (SLA) after the IOV of the whole constellation, hence mid-2025.

4. Operational concepts for each phase

4.1 LEOP

The activities during LEOP are ordered and managed by pass. For each activity, we determined on which pass it was uploaded, executed (immediate or time-tagged) and observed. The LEOP timeline was constructed satellite by satellite and operational role by operational role to know exactly what was to be done and when.

The same chronology was used for the 5 planes (only the launch time was different). This enabled the teams to capitalize the experience from one LEOP to the next one and to quickly implement optimizations according to the return of experience. This also enabled us to alleviate the dress rehearsal for the 3rd LEOP and to skip the dress rehearsals for the last 2 LEOPs (the LEOP rhythm was sufficient to ensure that the teams did not need a refresh on the procedures).

All activities were coordinated via a voice loop by role. An Operational Coordination Group (OCG) report concluded each shift to enable the handover between shifts and to conclude the different phases. All teams (experts **and** ops teams were located in the same room to ensure close coordination.

The LEOP lasts 48h max (more likely 24h). All data is retrieved post-pass to have the TM as soon as available. TC activities are not automated and are manually managed by the flight operations engineers.

There was only one flight engineer per satellite (compared to two usually) and one coordinator for the flight team.

The TCs are generated by the FOE team before each LEOP pass according defined procedures thanks to tools that limit the error risk of typing mismatch.

4.2 IOV

The activities during IOV are organized by topics with a list of activities to perform (preparation of nominal mode, payload IOV, propulsion IOV). Each topic can be subdued in several phases (for propulsion for example, cold commissioning #1 et 2, hot commissioning #1 and 2, calibration).

Each day, we list the activities to perform. We schedule as many satellite passes as possible to the plane in IOV (compared to other satellites in other planes). We try to perform the activities in parallel on the 5 satellites, except for critical activities like propulsion.

There is no voice loop coordination, activities are listed in the OCG report.

The IOV lasts several weeks and activities are performed during office hours (besides some critical activities that can be handled during extended hours). All TM data is retrieved every 3 hours and not after each communication pass to satellite (routine timeline) and can be retrieved on-demand if needed. TC activities are not automated and are manually managed by the flight operations engineers. Some sequence templates (large sequence of TCs) are used to generate complex activities to avoid human mistakes.

The fact of having 5 successive LEOPs enabled the team to capitalize from one IOV to the next (as seen hereabove for LEOPs) and to optimize the activities' sequences (both in length and in content).

4.3 Routine

The prime objective of the routine phase is to cope with IoT and AIS missions providing the service level agreed with the users.

The routine operations phase is expected to last at least 8 years.

From the satellites point of view, the main routine operations to perform at ground level are:

- Station keeping (orbit determination and maneuvers computation)
- Satellite-stations passes computation and allocation
- Ground-board time correlation
- Uplink of telecommands schedules:
  - Ground stations passes (Tx management and Housekeeping Telemetry (HKTM-R)/ Payload Telemetry (PLTM) downloads)
  - Onboard time update
  - Onboard orbit update
- Processing TM from satellites (every 3 hours in the GCS, after each pass by the MCS)
- At payload level, the main routine activities to manage at ground level are:
  - Routine monitoring
  - Computing missing frames and related TC plans for retrieval.

The payloads are quite autonomous and require few maintenance activities from ground.

At mission level, the main routine activities are:

- Uplink of allcast messages broadcasted to provide information on the Kinéis system:
  - Satellites ephemerides
  - Constellation status
  - Time.
- Uplink of device commands requested by the users

In addition, there is monitoring of the whole ground system (connections, applications' status…). Most routine activities are generated by dedicated software tools and automations in order to limit human interaction. An alerting system is implemented to alert operators in case of problem. An on-call team is available to deal with problems outside working days/hours.

4.4 Collisions

As a baseline, the collision risk assessment process is automatically performed every day (in the afternoon), as part of the routine activities. We expected most of the risks (alerts raised) to be managed in this frame, i.e. during working hours (week-end included) but it was not always the case until now.

In case a collision risk alert is raised:

- During working days: as part of the automatic process, the risk is mostly automatically managed. The decision to implement the risk mitigation action (maneuver plan) remains the decision of the Flight Director (FD).
- Other cases (short notice during working days and non-working days): the same procedures apply but the risk is supervised/managed by the on-duty team:
  - FDS for the computation of the mitigation plan and direct communications with the EUSST team
  - FOE for maneuver TC upload
  - Ground Operations Team (GOT) for the supervision of the ground segment
  - Mission manager for coordinating the GCS activities
  - FD for deciding on the risk mitigation action.

5. Results and Discussion: First feedback on Kinéis operations

The planning was tight, as expected, and the operations have not always been calm and easy. Handling 25 satellites is especially complex when you face different anomalies on different satellites.

Wisely we automated as much as possible and this saved time was used to focus on on-flight anomalies. Some of these anomalies could be fixed, some could be bypassed and for the other ones we had to change some concepts we had defined.

In this context, the primary skills of the operation team were adaptability, agility, responsiveness and team spirit. The challenge of operating 5 LEOPs in such a short time (9 months) and with launch date uncertainties (as they always are) was a hard constraint on the team's personal lives.

6. Conclusions

For this kind of projects, teams should be prepared in advance and the constraints on teams well perceived by the management to support them. That was the case for this project and it helped us face this challenge.

Technical skills are important to meet the project challenge but human skills must not be overlooked. The team composition balance is essential. And the team management must focus both on solving the technical challenges but also maintaining a good team spirit and motivation on the long term.