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DEPENDABILITY AND SAFETY FOR REUSABLE FIRST STAGE DEMONSTRATIONS AT GUIANA SPACE CENTER: FROM CALLISTO TO SKYHOPPER

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Abstract
On the French roadmap to reusability, while FROG prepares for its second flight test campaign and CALLISTO enters its qualification phase, CNES initiated end of 2024, a last demonstration step called SKYHOPPER. It aims to demonstrate the recovery and reuse capability of an operational launcher first stage taking off from the CSG. The implementation of this full-scale demonstration will tackle the novelties of reusability from both technological and operational aspects. The paper will introduce SKYHOPPER and its development logic, then will focus on some challenges specific to the demonstration, from a dependability and safety point of view.

1. Introduction

Reusability of the first stage is one of the key assets for competitive access to space for next generation of European launchers. It allows cheaper and more flexible launch system exploitation models. Reusability requests the mastering of several new technologies and flight domains and implies many new challenges including from a dependability and safety point of view.
Since 2015, along with institutional and industrial partners, CNES initiated several major demonstration projects for first stage reusability, encompassing several scales and types of demonstrators [1], [2], [3].

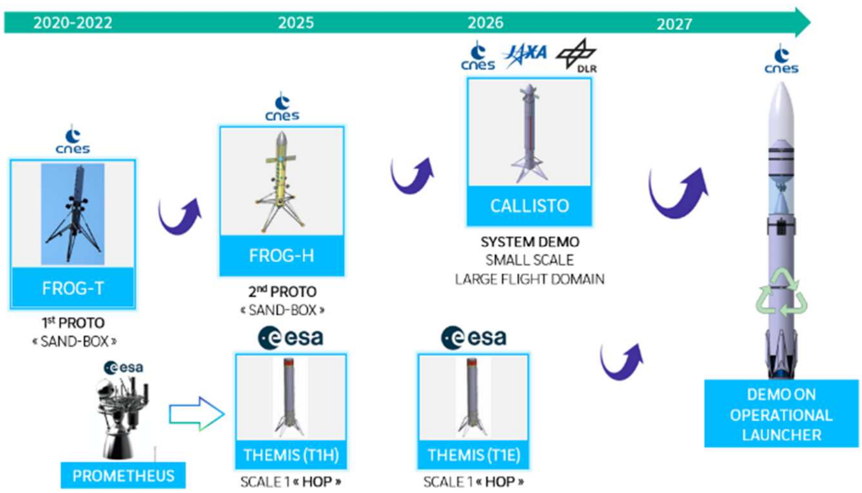

Figure 1 : CNES demonstration roadmap for first stage recovery & reuse

Among those projects, the most ambitious ones, launching from French Guiana Space Center, are CALLISTO and the demonstration on an operational launcher dubbed SKYHOPPER. Both will tackle the demonstration of a recovery in toss-back mode, which involves in-flight engine re-ignition, aerodynamic control surfaces, and vertical landing on

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deployable legs (on barge or on site). Previous European studies have shown that this recovery method is the most suitable for future evolutions of European institutional launchers, including heavy-lift vehicles in the Ariane class [4].

1.1 CALLISTO

Before starting a full scale development program with industry, CNES wanted to address first-hand the problematics of reusability on a lower scale, lower cost, lower-risk approach while tackling all the major challenges, including cryogenic propellant management during flip-over manoeuver, hybrid (GNSS & Inertial) navigation, guidance and control on very large flight domains and with additional actuators (aerosurfaces), as well as associated carrying-load structure sizing methodologies. Mastery of landing phase, post-landing safing and overhaul operations in-between flights were also identified as key objectives that needed a full launch system demonstration.

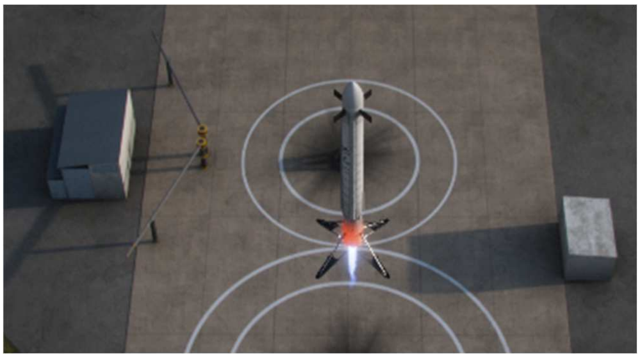

Figure 2 : CALLISTO landing in French Guiana Space Center, artist's view (@CNES/orbital dreams 2023)

Studies started in 2015 to investigate various options and partnership and CALLISTO project was officially born in 2017 as a cooperation action between JAXA, CNES and DLR [5]. CALLISTO development status is now in between critical definition phase and qualification phase depending on the sub-systems , with already several major flight items manufactured and under testing [2]. The vehicle is planned to arrive in French Guiana in 2026 after vehicle integration in Tsukuba and testing in Noshiro, in Japan.
The vehicle is 13 m high for 1.1 m diameter, weighs roughly 4 tons at lift-off and is powered by a reusable LOX/LH2 Japanese engine capable of providing 16 to 46 kN of thrust. Embedding all the necessary technologies for reusability, CALLISTO will cover a significant flight domain with trajectories going above 10 km and above Mach 1 and will allow validation of numerous models. The first flight tests will be hops, starting with legs already deployed, while the final flights will use in-flight leg deployment.

1.2 SKYHOPPER

The final step of the CNES first stage reusability roadmap is to demonstrate the end-to-end recovery and reuse of a first stage directly on an operational launcher taking off from the French Guiana Space Center and which main mission will be to place payload on orbit (as per figure 3). The purpose of relying on an operational launcher is to reduce overall demonstration costs by avoiding the development of dedicated ground facilities and focus on the maturation of technologies enabling launchers reusability.
ArianeGroup and MaiaSpace were selected to implement this demonstration and the project which started in autumn 2024 was named SKYHOPPER [6]. The demonstration will be performed on the MaiaSpace commercial mini-launcher, while preparing future reusable launchers and benefitting from ArianeGroup’s technical heritage from CALLISTO (Guidance & Control algorithms, transient phases simulation capability), Themis [7, 8] and Prometheus® [9] heritage.

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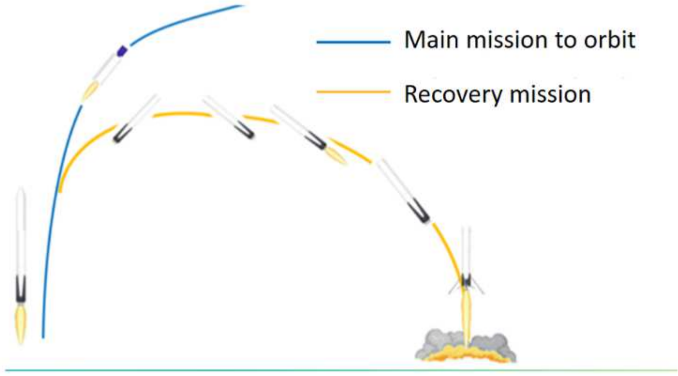

Figure 3 : "Passenger" recovery demonstration on an operational launcher

The first stage of MaiaSpace launcher is a “C200” stage using liquid oxygen (LOX) and liquid methane (LCH4) and powered by 3 Prometheus® engines. Main diameter is 3.5 m (tank cylinder), for a total length of ~35 m. The stage features two variants and operating modes, either “expendable mode” (ELV, Expandable Launch Vehicle) or “reusable mode” (RLV, Reusable Launch Vehicle) depending on mission needs. ELV configuration is being developed at MaiaSpace level; adaptations for the RLV configuration are the purpose of SKYHOPPER. The reconfiguration from ELV to RLV is achieved by adding systems specific to recovery needs, mainly Landing Legs and Flight Control Bay equipped with specific devices (avionics, aerodynamic control surfaces and attitude control system, as shown in Figure 4).
Another enabling system for the demonstration is an equipped maritime barge and associated mechanical, fluidics and electrical means, whose main objectives are to enable the landing of the first stage and its transfer back to the French Guiana harbour.

Figure 4 : MaiaSpace ELV & RLV versions

The final demonstration consists of the following steps:

- The launch is performed from Kourou Guiana Space Center (CSG)
- Ascent flight (boost M1) is performed through MAIA launcher
- First stage is separated from second stage, which continues its way towards orbit
- First stage follows a ballistic trajectory;
- A braking boost is performed during the supersonic phase of the reentry (to limit dynamic pressure and thermal fluxes)
- After the braking boost, a second ballistic phase occurs during which guidance & control is performed using Grid Fins System (GFS)
- Finally, a landing boost is performed during which the landing system deployment occurs, and the first stage lands on a sea barge for SKYHOPPER demonstration
- Immediately after touchdown and stabilization of the first stage on the sea barge, the safing operations start, thanks to robotic means
- Maritime transport back to harbour (baseline: Kourou Pariacabo) and then to CSG
- Maintenance and refurbishment operations in CSG facilities
- Refly in ELV configuration on another MaiaSpace commercial launch.

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2. Applicable regulatory

The recovery and reusability of a vehicle raise significant safety-related challenges, both from ground/sea-based operations and in-flight perspectives. An overview of some of these challenges and the associated solutions is provided in the next sections.

2.1 General context

i) French Space Operations Act (FSOA)
The French Space Operations Act (FSOA – 2023 edition) sets up a consistent regulatory framework to authorize and monitor space operations under French jurisdiction or for which the French Government bears international liability as a Launching State.

ii) Technical Regulation (RT-NG)
All space projects that launches from CSG must comply with the French regulations. In particular, the Technical Regulation (RT-NG – 2024 edition) sets out the safety objectives to be achieved for space operations.

iii) REI and REI-NG
Another text serves as a regulatory framework: the order regulating the operation of the Guiana Space Center facilities (REI – 2010 edition), which sets the ground and flight safety rules and is the reference for carrying out all activities at CSG. It covers all operations to be performed before and after the vehicle's lift off, as well as the definition of the vehicle's safety features, notably with regard to the MSI (Safety and Intervention Mission) during the flight itself. A new version of this text called REI-NG (New Generation – 2025) is forthcoming and will be applicable soon.

It is worth noting that the RT-NG and the REI-NG, will cover the phases generated by reusable launchers, such as the recovery of the first stage and the landing (RTLS or down range).

2.2 Specific context

i) CALLISTO case
Although the regulations could have been customized thanks to the demonstrator and its sub orbital nature, the project team decided to make it compliant with the FSOA, as a core objective of the project.
The goal to apply these requirements to CALLISTO was to demonstrate the capabilities to fly and recover space transportation vehicle from CSG under the most demanding safety standards and to pave an easier way for future operational vehicles.

ii) SKYHOPPER case
In the case of a stage recovery on a barge at sea, it should be noted that the RT-NG is no more applicable after the landing, nor the REI. For the period between the landing and the return to Pariacabo harbour, the maritime transportation must comply with environmental protection requirements under International Maritime Organization conventions (IMO) and International Maritime Dangerous Goods Code (IMDG).
After the arrival at Pariacabo harbour where the REI applies, the road transport of the recovery stage to the CSG must comply this time with European Agreement concerning international carriage of Dangerous goods by Road (ADR). It is only after the stage has reached the CSG entrance that the REI becomes applicable again. Figure 5 provides an overview of applicable regulations along SKYHOPPER life phases.

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Life phases	Applicable regulations
Launch preparation operations	French Labor Code REI Environmental code
Flight phase (from lift-off to landing)	REI until end of MSI RT-NG
Maritime transport	International Maritime Organisation conventions International Maritime Dangerous Goods Code
Pariacabo harbor	French Labor Code REI Environmental code
Road transport	European Agreement concerning international carriage of Dangerous goods by Road
Refurbishment operations	French Labor Code REI Environmental code

Figure 5 : Synthesis of applicable regulations to SKYHOPPER along life phases

3. RAMS issues and challenges

For all vehicle launched from CSG, it is necessary to comply with French safety regulation during pre and post-flight operations on ground and during flight phases. Nevertheless, the other dependability characteristics (reliability, availability and maintainability) to be achieved are at the discretion of the projects.

3.1 Dependability & Availability objectives

3.1.1 CALLISTO objectives

When compared to standard ELV operated at CSG, CALLISTO has unique features with impact on its safety and dependability [10]:

- The vehicle does neither feature solid propulsion nor highly toxic liquid propellants
- The pyrotechnics is limited to FNS (Flight Neutralization System) itself since there is no stage or fairing to separate
- The size of the vehicle is very small when compared to other ELV operated at CSG
- The quantities of rocket propellant (LOX and LH2) are a few metric tons,
- There is no local production (or AIT) facility
- The vehicle is supposed to be recovered
  - ✓ There is the need to address carefully post-landing operations ahead of staff access to Landing Zone,
  - ✓ Interfaces with Launch range have to be customized accordingly.
  - ✓ Vehicle is supposed to fly ten times with very different flight features (duration, altitude ceiling)

CALLISTO project decided not to specify any quantitative level of reliability for the vehicle itself and its products, beside the Flight Neutralization System (FNS). Rationale is that the product reliability for a single shot demonstrator with significant number of COTS items is mastered via the verification strategy for environmental requirements (e.g. vibrations, temperature, pressure variation).

CALLISTO reliability policy may be summarized as follows:

- Reliability of ground-based systems shall be, at least, an order of magnitude greater than vehicle and are based on qualitative requirements
- Reliability for vehicle products relies on risk analysis and a set of qualitative requirements is derived accordingly.

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		Qualitative criterion		
		Two-fault tolerance	Fault tolerance	No fault tolerance
Severity	**Catastrophic** – loss of human life or irreversible damage to the environment	Acceptable	**Not acceptable**	**Not acceptable**
	Severe – loss of mission	Acceptable	Acceptable	- Fault tolerance requirement for ground operations - Acceptable in flight
	Availability	The system should enable 10 flights in 6 months		
	No effect	Acceptable	Acceptable	Acceptable

Figure 6 : CALLISTO Risk acceptance matrix

3.1.2 SKYHOPPER objectives

The following objectives have been defined to ensure the dependability and safety of launch and recovery operations of the SKYHOPPER system:

❖ Safe recovery

In the context of a reusable first stage recovered at sea, new life phases are analyzed in order to master safety through the whole lifecycle. In particular, the recovery flight phase (from toss-back maneuver to vehicle landing), and the ground recovery phases (vehicle passivation, maritime and road transportation and refurbishment) introduces new risks that are handled with the same criteria as for ELV configuration.

❖ Limit impact of reusability regarding mission reliability

From lift-off to first stage separation, the unreliability introduced by the RLV systems on ELV ascent flight performance shall be low (predefined value), in comparison to the ELV initial performance.

❖ Successful return flight demonstration

In order to maximize the chance of success within a demonstration logic, the risks of a return flight failure are identified and possibly mitigated after a case-by-case assessment. Thus the risk management policy is adapted to make the demonstration reliable and convincing, even if the system is not yet optimized for full operational services.

❖ Availability

In addition to the already known constraints of launch campaigns, reusability introduces new sources of launch unavailability related to the objective of successful first stage landing and recovery.
Those can be of different types, such as:

- Failures of additional means in comparison to ELV configuration (RLV systems, status of launch recovery segment)
- Unfavourable weather conditions for landing success at the recovery zone (wind, sea state, swell)
- Unfavourable weather conditions for maritime transport back to the harbour during the time window

The project follows an incremental development approach, whereby technical and functional challenges evolve or emerge progressively. Figure 7 summarizes the key dependability and safety challenges associated with each development step.

Step	Description	Dependability and Safety challenges
1	Mastering of first stage engine re-ignition during re-entry phase after 1 / 2 separation	1) Ensure a safe return flight 2) Avoid the creation of a maritime wreck that could constitute a hazard for maritime navigation
2	First stage re-entry with mastering of velocity and location of impact area (conformity with recovery scenario)	
3	Mastering of first stage Landing & Safing on a barge at sea for an RLV	3) Manage a reliable return flight and landing 4) Deal with recovery segment availability 5) Ensure safety of people involved in launch and recovery operations 6) Ensure vehicle safing operations 7) Monitor vehicle health status to authorize ground operations
4	Mastering of first stage transport back to CSG	8) Ensure safe transportation of a flown vehicle on public area

Figure 7 : SKYHOPPER objectives with regard to demonstration

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3.2 General Safety objectives

Two hazard class categories are defined by the REI (and REI-NG), for both ground-based and in-flight activities, according to the severity of the damage.

Hazard class	*Definition of damage*
Hazard with catastrophic consequences	• **Immediate or delayed loss of human life** • **Permanent invalidity** • **Irreversible harm to public health**
Hazard with severe consequences	• **Serious injury to individuals leading neither to loss of human life nor permanent invalidity** • **Reversible harm to public health** • **Significant property damage** : - Total or partial destruction of public or private property - Total or partial destruction of a facility critical to the launch operation • **Significant environmental damage**

Figure 8 : Risk classification for ground-based and in-flight activities

3.2.1 CALLISTO objectives

Safety regulations applicable in CSG are guidelines disregarding its specific features that does not make it a space object as defined by French Space Operation Act (FSOA).

3.2.2 SKYHOPPER objectives

Safety regulations applicable in CSG are mandatory requirements that must be submitted to CNES Safeguard authorities.

4. Flight Safety

In order to contribute to the safety of people and property and to the protection of public health and environment, the requirements concerning any in-flight hazardous system must comply with a clearly identified reliability objective compatible with the qualitative and quantitative requirements below:

Qualitative requirements
According to REI - articles 23 and 24, no combination of two failures in flight must present a risk of catastrophic or severe consequences (double failure criterion or FS/FS).

Quantitative requirements
Quantitative flight requirements are directly derived from the RT-NG – article 20, quantitative objectives for human safety:

- 2.10^{-5} for the flight phase between lift-off and the end of mission phase,
- 2.10^{-5} for the recovery phase of each launcher element designed to be reused.

4.1 CALLISTO issues

CALLISTO is the first vehicle to be recovered at CSG following a Return-To-Landing-Site trajectory. It is designed to perform a set of flights ranging from low altitude Hops to flights featuring High Altitude manoeuver.

On legacy expendable launchers, the flight safety assessment – i.e. the risk assessment on third parties and installations in case of vehicle failure in flight – is based on the outcomes of all other design activities, in particular trajectory definition, G&C performances and launcher characteristics e.g. structural design and Flight Termination System (FTS) architecture. But such method was not adapted to CALLISTO. The lack of in-flight experience regarding G&C

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achievable performances in particular for high altitude manoeuvre and re-entry and the development in parallel of 2 G&C systems led to adopt a Design-to-Safety approach designated as Flight Safety Corridor [11].

The Flight Safety Corridor is a kinematic interface specification, expressed as position, velocity and slope errors versus nominal trajectory along each altitude. It is used to check as early as possible the acceptability of a given trajectory. This specification is the baseline to define the limits beyond which the flight is terminated.
Flight safety assessment is performed to check that:

- The resulting debris fall within a safe area and,
- That the limits can be operated by the Flight Safety Officers in term of workload considering anticipated vehicle behaviour in case of failure (e.g. in case of malfunction turn).

4.2 SKYHOPPER issues

The recovery flight of a first stage following a Down-Range trajectory leads to new issues in terms of safety that must be tackled.
In a similar manner to expendable missions, it is necessary to ensure safety after stage separation considering the scenarios of loss of vehicle control or explosions either in flight or on ground. In fact, for the purpose of recovery flight, once separated the first stage remains a vehicle with an important propulsive capability.

To address these challenges, one shall demonstrate that the flying system is able to control its return trajectory and do not represent a threat to people, property, or the environment.

In specific scenarios, evaluated thanks to the flight safety assessment (RT-NG – article 7), such as returns exclusively over remote sea areas, the system may be considered intrinsically safe. In that case, and based on the validation of the CNES's president, simplified strategies to inhibit dangerous cases may be enough to comply with regulations. Afterward, the vehicle will re-enter along a predictable ballistic trajectory ended with a splashdown impact in a safe zone.

Recovery flight missions also brings out new risks related to the protection of the recovery segment. Among other risks it is worthy to mention the next scenario. In case of an anomaly during the recovery flight which decreases significantly the landing success, a decision from the mission control center could abort the landing attempt in order to avoid additional damages on ground assets. Thus, because the risk is limited to property damages, it would be under the assets owner responsibility to define its acceptability criteria taking into account the impacts in terms of repairing costs, return-to-service duration, etc.

❖ Human Safety

During the return flight, a perspective is to establish different criteria to protect people not involved in the launch operation (public) and to protect personnel directly involved in the launch recovery operation. Actually, the exclusion of recovery personnel from the debris footprint increases significantly the response time in the landing area. Especially in the context of operations at sea where traveling speeds are much lower than for ground operations.

5. Ground Safety

In order to contribute to the safety of people and property and to the protection of public health and environment, the requirements concerning hazardous ground-based activities must comply with a clearly identified reliability objective compatible with the qualitative and quantitative requirements below:

Qualitative requirements

❖ Activity with a risk of severe consequences: single failure criterion

No failure (single failure or human error) must entail a risk of severe, let alone catastrophic consequences (also known as "Fail Safe" (FS)).

❖ Activity with a risk of catastrophic consequences: double failure criterion

No combination of two failures (fault or human error) must present a risk of catastrophic consequences (FS/FS).

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Quantitative requirements

For all activities with a risk of catastrophic consequences carried out within the perimeter of the CSG, the maximum allowable probability of causing at least one victim (collective hazard) included in the design of the launch systems, test benches and associated technical resources, is 10^{-6} per launch preparation or test campaign.

NOTA: some differences exist between the previous REI and the REI-NG, particularly:

- For risks with severe consequences, the FS (single failure criterion) is no more required from the landing on site (RTLS) to the return to safe state,
- For risks with catastrophic consequences, the collective hazard probability is modified from *"10^{-6} per launch preparation or test campaign"* to *"10^{-9} per hour of exposure in the presence of personnel"*

A safety handbook will be published soon by CNES to guide launch operators in safety activities and submission process.

5.1 CALLISTO issues

The safety level to be reached during ground operations is defined by the REI, i.e. meeting the triple failure criterion before the occurrence of a catastrophic event (FS/FS criterion). For CALLISTO, it has been agreed between the project team and the safety authority that the probability of occurrence of a catastrophic event at 10^{-6} per campaign is satisfied by tolerating three independent failures (system at risk and two barriers). In cases where it is not possible to satisfy the FS/FS criterion, access to the hazardous area must be forbidden to personnel.

5.1.2 Operations prior to the flight

One concrete application is the use of cryogenic fluids. As hydrogen and liquid oxygen (LH2 and LOX respectively) are intrinsically dangerous when brought together, operations are carried out remotely as soon LH2 and LOX are used simultaneously to fill the vehicle's tanks.

Before the flight, the vehicle is connected to the ground fluid system (cryogenics, nitrogen and helium gas) and electrical system (power supply and Ethernet data flow). After the flight, it is necessary to put the launcher back to a steady state before allowing access to personnel. In particular, it is necessary to avoid hydrogen build-up in the vehicle compartments by ventilating them (using nitrogen gas) and avoid a geyser effect in the oxygen tank by ventilating the fluid system (using helium gas).

5.1.2 Safing of the vehicle post-flight

CALLISTO recovery introduces the need to have a post-landing safing procedure that would ultimately allow staff access to the vehicle under safe conditions.

After landing, time is running out for stabilizing the vehicle against rapidly divergent risks (fire, propellant boiling leading to self-pressurization) and for supplying electrical power, gaseous nitrogen and gaseous helium budget to manage mid-term divergent risks (thermal runaway, moisture contamination) and finalize propellant tanks cleaning.

The first step is achieved automatically at touchdown, triggering a sequence to:

- Shutdown the engine for mitigating the risk of fire,
- Set the hydrogen tank to outgassing and then prevent a risk of burst under self-pressurization due to hydrogen boiling,
- Keep pressure in oxygen tank and start helium injection to alleviate the risk of geyser effect, i.e. the creation of a massive bubble flowing upstream the oxygen feedline that can ultimately damage the vehicle.

The Flight Termination System is then remotely deactivated by Flight Safety Officers.

CNES decided to use a remotely-operated robot for the necessary services: fluids (helium and nitrogen) as well as electrical power and communication. The robot thus enables the safing of CALLISTO while guaranteeing the safety of people outside the vehicle's areas of effect.

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5.2 SKYHOPPER issues

5.2.1 Operations prior to the flight (AIT & Launch)

From a safety perspective, the introduction of the RLV-specific components on an expendable stage goes with potential new hazards related to products enabling reusability. These hazards shall be mastered throughout ground Assembly, Integration & Testing (AIT) and Launch operations.
Risks related to both electrical and fluidic systems are already mitigated through usual launch operations and remain applicable to the recovery systems. Furthermore, in RLV configuration, mobile mechanisms are introduced, such as landing legs and grid fins, that shares the feature of been externally mounted on the launcher. Then, ground safety requirements would request either mechanical and electrical barriers or operational constraints to prevent from hazardous inadvertent movement during operations.

5.2.2 On-barge safing of the vehicle and maritime transport

The vehicle passivation starts once it has landed on the barge and consists in managing the stage back to a “safe state to handle” prior to start maritime transport. The passivation is performed by robots remotely-operated. At the end of the safing sequence, hazardous systems are secured. It is a prerequisite to allow personnel access in the vicinity of the vehicle.

Even if the vehicle is in a safe stable state, the maritime transport phase back to the harbour is critical for its mechanical integrity. Weather conditions, wind and swell mainly, are a threat for the SKYHOPPER stability on the barge.
In case of fall into the water, regardless of the cause (landing attempt failure, vehicle tilting), French regulation imposes to avoid the creation of a maritime wreck that could constitute a hazard for maritime navigation.

5.2.3 Vehicle preparation for road transportation

At Pariacabo harbour, the REI regulation applies for ground operations. Thus, the authorization for docking is submitted to the demonstration of compliance with REI (and soon REI-NG) requirements. Once docked, mainly mechanical operations are foreseen on the barge to prepare SKYHOPPER for road transport in a horizontal configuration.

5.2.4 Safety during refurbishment operations

During refurbishment operations in CSG facilities, safety rules are similar to the ones applicable during launch preparation. The challenge towards a profitable reusability is to reduce recurring costs relative to maintenance operations. This require to:

- develop products that are robust to flight conditions,
- have a very high coverage tests and validation ability,
- be able to repair or replace easily products when needed to.

Flown stages diagnosis based on health monitoring assessment [12] will be crucial to enable high launch cadence.
At the end of the refurbishment phase, re-flight worthiness is declared meaning that the stage is compatible with the next mission dependability and safety objectives.
Thus the SKYHOPPER demonstration will pave the way to an optimized maintenance and validation logic to declare re-flight worthiness that is a key feature for full operational services.

6. Way forward

Only some few examples were addressed in this paper, but there are many other important RAMS issues already tackled or to be solved. On CNES side, flight safety issues are the focus of attention, and a task force has been set up, notably to provide the best possible response to the need to manage and track several objects at the same time (first stage in its recovery phase while second stage continuing its mission). All efforts are mobilized around these ambitious projects with the determination to be ready for reusable rockets from CSG in the safest conditions, in a near future.

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References

[1] Tatiossian, P. et al. 2025. Progress in preparation of a small scale and low-cost flying test bed for reusability: FROG-H, *11th European Conference for AeroSpace Sciences, Italy,* EUCASS2025-441

[2] Illig, M., Ishimoto, S., and Dumont, E.. 2024. A reusable launcher 1st stage demonstrator for Europe and Japan: CALLISTO, *75th International Astronautical Congress, Italy,* IAC-24-D2.6.1

[3] Cliquet Moreno, E., Miot, D., and Oriol, S.. 2025. Overview of R&D activities on launcher's first stage reusability led by CNES Space Transportation Directorate, *35th International Symposium on Space Technology and Science, Tokushima, Japan*

[4] Gogdet, O., Mansouri, J., Breteau, J., De Mirand, A. P., and Louaas, E. 2019. Launch vehicles system studies in the "future launchers preparatory program": The reusability option for Ariane evolutions, *8th European Conference for AeroSpace Sciences,* EUCASS2019-971

[5] Illig, M., Ishimoto, S., and Dumont, E..2022. CALLISTO, a demonstrator for reusable launchers, *9th European Conference for AeroSpace Sciences*, EUCASS2022-7239

[6] Delattre, N. 2025. One the road to European reusable space launcher, *11th European Conference for AeroSpace Sciences,* EUCASS 2025-714

[7] Bertorello, C., Gogdet, O., Breteau, J., Tincelin, Y., Cliquet-Moreno, E., Coletti, E., and Bensalem, S..2022: Themis Demonstration Programme, *73rd International Astronautical Congress*, Paris, France, IAC-22-D2.6.5

[8] Jousset, F., and Villefumade, A..2025. ESA FLPP reusability demonstrations: perspectives, *11th European Conference for AeroSpace Sciences,* EUCASS2025-448

[9] Iannetti, A., Girard, N., Tchou-Kien, D., Bonhomme, C., Ravier, N., and Edeline, E..2017. PROMETHEUS, a LOX/LCH4 reusable rocket engine, *7th European Conference for AeroSpace Sciences,* EUCASS2017-537

[10] Outin, C., Biard, A., Mauries, A., Chavagnac, C., Davezac M-L.. 2024, CALLISTO – Flight demonstrator for future reusable launcher reliability, *24th Lambda Mu Congress, France,* hal-05016331

[11] Mezard, P., Cesco, N., Praly, N.,Monchaux, D., Clauzon, T., Desmariaux, J.. 202X. CALLISTO, a safety demonstration of future reusable launcher stages from CSG, *9th European Conference for AeroSpace Sciences,* EUCASS2022-7163

[12] Akbaraly, M., Le Gonidec S., Garnier T., A. 2024, Dependability & Safety viewpoint on the Integrated Vehicule Health Management of reusable liquid propulsion engines, *24th Lambda Mu Congress, France*, hal-05016343