SIROM Roadmap for Future In-Orbit Servicing Applications

Montserrat Díaz-Carrasco[1], Alejandro Lázaro[2], Ana Ruiz[3], Marta Centeno[4], José Gala[5], Javier Viñals[6]

[1]*SENER Aeroespacial, Severo Ochoa, 4, 28760 Tres Cantos, Madrid (Spain), montserrat.diaz@aeroespacial.sener*
[2]*SENER Aeroespacial, Avd. Zugazarte, 56, 48930 Getxo, Bizkaia (Spain), alejandro.lazaro@aeroespacial.sener*
[3]*SENER Aeroespacial, Avd. Zugazarte, 56, 48930 Getxo, Bizkaia (Spain), analuisa.ruiz@aeroespacial.sener*
[4]*SENER Aeroespacial, Severo Ochoa, 4, 28760 Tres Cantos, Madrid (Spain), marta.centeno@aeroespacial.sener*
[5]*SENER Aeroespacial, Severo Ochoa, 4, 28760 Tres Cantos, Madrid (Spain), jose.gala@aeroespacial.sener*
[6]*SENER Aeroespacial, Avd. Zugazarte, 56, 48930 Getxo, Bizkaia (Spain), javier.vinals@aeroespacial.sener*

1 INTRODUCTION

In the context of In-Orbit Servicing (IOS) and In-Space Manufacturing and Assembly (ISMA), Standard Interfaces (SI) are central building blocks for the automation of the processes. For this purpose, SENER Aeroespacial started developing the SIROM interface in the frame of European Union's H2020 and has kept improving the design to aid future orbital missions and space standardization.

Since the beginning of the SIROM project, SENER Aeroespacial has collaborated in European projects to perform on-ground demonstration of orbital scenarios. Some of these projects have been:

- EROSS [1], led by Thales Alenia, for Orbital Replacement Unit (ORU) manipulation.
- PERIOD [2], led by Airbus, for ORU manipulation and including a benchmark of the three main SIs in Europe.
- MIRROR [3], led by GMV, for in-space assembly of hexagonal mirrors with a three-legged robot.

These projects have contributed to the development of the SIROM by including stakeholders in the mission scenarios definition for the SI, which provide useful feedback for the design.

In this paper, the improvements and optimizations made in the SIROM family of products are presented, along with the roadmap of future SIROM applications for IOS and ISMA.

2 DESIGN DESCRIPTION

In the past year, the SIROM has been redesigned to upgrade its functionality. The work has been focused on producing three new versions, SIROM families E, F and G, explained in section 2.2. Many of the improvements in these families are related to three aspects:

- Developing a family-oriented line of products.
- Developing and validating the refuelling interface.
- Adapting the design for flight applications.

The upgrades included in new versions and the rationale behind each aspect is detailed in this section.

2.1 Design upgrades

Independently from the specific version of the new SIROM families E, F and G, the design has been upgraded to improve implemented functionalities or include new ones. This section describes such changes.

2.1.1 Mechanism

The mechanism keeps the basic principle of the previous version to maintain heritage, but it has been modified to increase the strength of the latches and to include the ESD cover pulling in the operation.

In SIROM C, the latching was continuous from fully open to fully closed, and once the mechanism was coupled there was electrical connection. In the last part of the latching, the connectors plate was elevated to make contact with the passive side.

This concept was upgraded to include an ESD/dust cover that protects the exposed contacts. Now the latching is done in two steps, adding a second BLDC actuator:

- First, the latches are closed using the first actuator, capturing the passive side and aligning both interfaces with the guiding petals.
- When the corresponding sensors have been activated, the second motor performs the deployment of the connectors plate, pulling the cover to allow connection.

Once the operation is complete, electrical connection is stablished and verified by two flags: a sensor placed on the connectors plate that senses the deployed position, and the mating pin, already present in previous versions.

For passive SIROMs, the cover also needs to be pulled to allow connection. In order to keep the volume to a minimum, placing an actuator inside the passive model was discarded early in the design process. The final version includes a pushing rod on the active side that activates the mechanism on the passive side, pulling the covers at both sides simultaneously.

This mechanism is the same for families E, F and G. In family F and G, the second phase also deploys the fluidic connector in the same movement.

Additionally, the shape of the connectors plate, petals and latches has been unified for families E, F and G. This allows the manufacturing process to group elements and therefore improves the supply chain management.

The resulting mechanism offers a traction force of 3 kN, considerably more than the previous version (1.3 kN). The compression and radial loads are the same, 5 kN each, while the torque has increased to 480 Nm. These values are the same fo

2.1.2 Sensors

For the latching operation, the phases are detected by hall sensors placed inside the SIROM mechanism. For the new families, these sensors have redundancy to increase reliability of the operation.

In previous versions, the open and closed positions of the latches were sensed by a single hall sensor. For the new version, each phase (latching and connectors deployment) is tracked at the start and end of the movement by redundant hall sensors. Therefore, a total of 8 sensors are included for position control.

Additionally, to confirm the electrical connection, an electrical signal is sensed by the electronics, referred to as “mating pin”. This is only active once both plates are in contact.

As a navigation aid, proximity sensors have been included to help the docking operation. Two hall sensors are placed on the top of the case, which detect the magnet placed on the passive side. This information may be used to check the position of the SIs prior to starting the capture.

2.1.3 Electronics

The electronic subsystem has also been updated for these versions. One of the main improvements of the board is the EEE selection, which is explained in section 2.4.3.

In terms of operation, the state diagram has been updated to include all states:

- Stand-By: SIROM accessible by TM/TC, actuators switched off. The position of the latches can be either RTC or CON. A command is needed to exit this mode and become operational.
- RTC (Ready to Capture): open latches, ESD covers connectors plate.
- LAT (Latched): closed latches and SIs in contact, ESD cover still in place. Mechanical coupling only.
- CON (Connected): ESD cover pulled and connectors deployed. Mechanical and electrical coupling completed.

The states are common to all new SIROM versions (E, F, G), since the operation of the mechanism is the same.

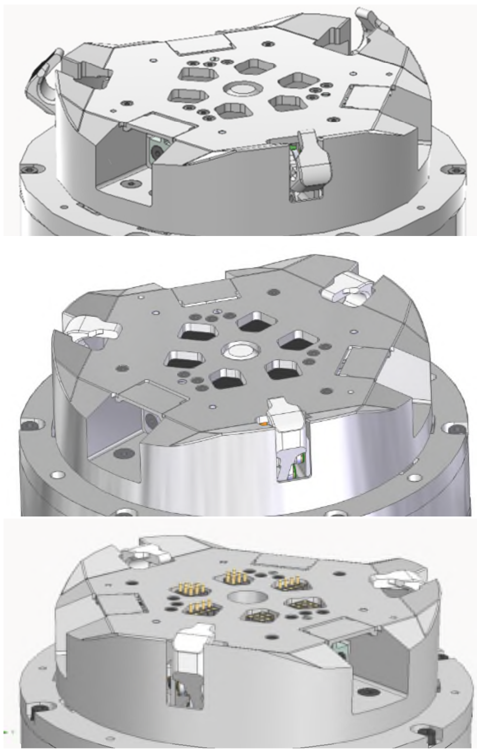

Figure 1: Latching operation, from RTC (up), LAT (middle) and CON (bottom)

Regarding the hardware, the circuits have been modified to include a second motor driver circuit and acquisition circuits for all hall sensors. Since the motor and sensors are the same as the ones used in previous versions, these blocks have already been tested extensively.

For all new families, the electronic subsystem is placed in a single PCA instead of the previous two. This allows the integrated SIROM to reduce volume and an easier assembly of the units. There are two physical versions of the subsystem: one integrated with the mechanism for SIROM family E, and another external unit for all families (mandatory for F and G).

In terms of the power block, the design has been modified. Firstly, the electronics no longer include control of the power transfer across the board, since it was shown in previous projects that a higher power transfer bypass is preferred. Therefore, once the SIROMs are electrically coupled, the connection is ready for power transfer, which must be commanded externally.

Additionally, the power supply block has been redesigned. For the new families, the voltage supply is no longer limited to a single 28 V bus like families B and C. Now, there are several options to adapt to mission scenarios. Figure 2 shows the available power buses, which are:

- High-power: this bus is only for power transfer bypass. It does not interact with the electronics, and its control is outside of the SIROM scope.
- *Vbus* (nominal 28 V): the purpose of this bus is the same as previous versions. The SIROM electronics can be powered using only this bus, and it can be used for low-power transfer to power-up other SIROMs or small payloads.
- *Vmotor* (nominal 24 V): this bus is optional, for cases where the motor needs to be power independently. It is not passed through to the connectors plate. If not provided, the motor is powered with *Vbus*.
- *Vdriver*/*Velec* (nominal 15 V/5 V): both buses are meant for the SIROM electronics. It is useful in applications where these buses are already generated in the system, such as Cubesat architectures. If not provided, they are generated from *Vbus* or *Vmotor*.

This architecture allows several configurations to adapt to the mission, and it is especially well-suited for Cubesat applications. The SIROM could be powered through a single bus, or through the internal buses (Vmotor, Vdriver, Velec) generated by an internal power subsystem. However, this architecture does not provide isolation between the different supplies. If not provided externally, a DC/DC converter board could be added for the External electronic unit option.

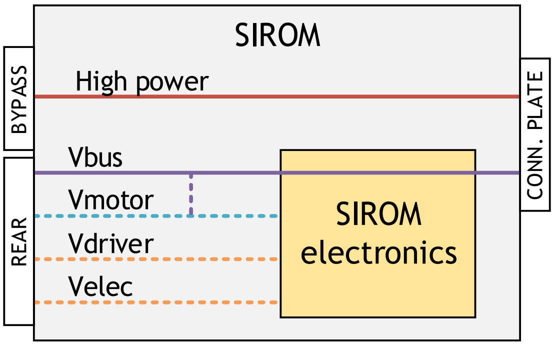

Figure 2: Power supply functional diagram

The microcontroller has been changed from SIROM C to a more powerful model from Atmel. It now includes two CAN controllers to provide full redundancy of the communication bus, which increases the reliability of the unit. The change of component also comes from SENER's Preferred Part List for NewSpace, which helps unify components among projects to reduce costs.

Lastly, the control system has also been modified to include the redundant hall sensors present in the mechanism. A simple failure detection strategy has been designed to detect most common failures in case one pair of sensors is not reporting the same state.

The first prototype of the new SIROM electronics has already been manufactured and tested at functional block level to lower the risks associated with new designs. The results have been successful.

2.2 Family-oriented product

The first version of SIROM in 2018 (named SIROM A) was developed as a prototype for TRL 3 validation [4]. This version included data, power and fluidic connectors, but the electronics was not integrated in the design.

The next version (SIROM B) was the first integrated version of the family [5]. Apart from this, the main change comes from replacing the connectors with spring-loaded pins to allow capture with lower forces and small misalignments in the operation. This version was submitted to an environmental test campaign to evaluate the system as a whole, which was passed in 2021.

SIROM C is very similar in functionality, including high power lines as the main improvement. Also, the petals were modified to allow a wider capture range, especially designed for triple-docking set-ups like the one used for MIRROR [3].

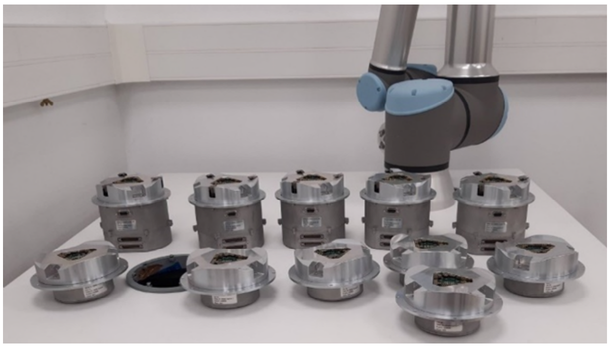

Figure 3: SIROMs (Family C) produced for MIRROR

At this point, gathering the experience from previous SIROM versions, SENER has identified that one of the main issues of the manufacturing process was high lead times and costs. To minimize this problem, the new versions have been split in three families that share common elements as much as possible. These families are:

- SIROM E: data and power transfer.
- SIROM F: only fluidic transfer, no electrical connectors.
- SIROM G: fluid, data and power transfer.

These three families include the design changes already detailed in section 2.1.

2.2.1 SIROM Family E

SIROM E is the direct evolution of SIROM C, including power and data transfer without a fluidic connector.

Figure 4 shows SIROM E versions Active and Passive. Family E characteristics are shown in Table 1.

This family of SIROMs includes three versions:

- Active/Androgynous: actuated SI, able to latch to a passive model or to another active acting as passive (hence, androgynous). There are two active models:
  - Integrated version (X01): mechanism and electronics are contained in a single envelope.
  - External electronics (X02): electronic subsystem is housed in a separated box, following a modular approach for stackable boards.
- Passive: only includes mechanical interface and connectors plate, without actuator or electronic subsystem inside to allow reduced volume and mass.

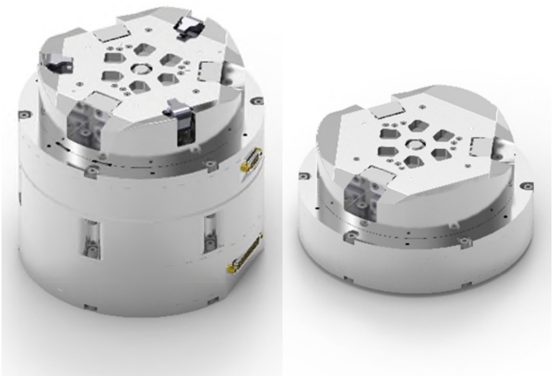

Figure 4: SIROM E (Active and Passive)

SIROM E Active		SIROM E Passive	
Mass	1.85 kg (X01) 1.5 kg (X02)	*Mass*	0.35 kg
Height	123 mm (X01) 102 mm (X02)	*Height*	69.5 mm
Elect.	Integrated (X01) External (X02)	*Elect.*	No

Table 1: SIROM E characteristics

In a connection between two SIROMs, the active side actuates the latches to perform the capture. Once both surfaces are in contact and aligned due to the guiding petals, the ESD cover is pulled from both sides using the actuator on the active SIROM.

For data transfer, two options are provided: CAN bus, which is used internally to command the SIROM mechanism, and Ethernet (or similar protocols) for high-speed data. The CAN bus offers main and redundant lines, given the importance of the line for TM/TC.

For power transfer, SIROM offers up to 15 A/100 V lines for demanding equipment, such as battery packs or high-power payloads. *Vbus* (nominal 28 V) is also available for low-power payloads, which is used if needed to power-up other SIROMs in the bus.

2.2.2 SIROM Family F

SIROM F only includes the fluidic interface, while maintaining the same elements for the latching mechanism. This version does not include a connectors plate, and thus the ESD cover is unnecessary, so it has been removed to simplify the design.

The active version is shown in Figure 5. The passive version is very similar, changing mainly the fluidic connector and the height of the interface. SIROM F characteristics are shown in Table 2.

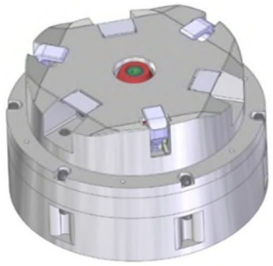

Figure 5: SIROM F (Active)

In both families F and G, the fluidic connector goes through the mechanism. Therefore, the electronic subsystem cannot be integrated with the mechanism, using instead the External electronics box described in the previous section.

This family is not foreseen to be used in a current project, so its design is less detailed than E and G. However, the key characteristics of the fluidic interface are identical to SIROM G. Thus, it is detailed in the next section.

SIROM F Active		SIROM F Passive	
Mass	1.4 kg	*Mass*	0.5 kg
Height	102 mm	*Height*	109 mm
Electronics	External	*Electronics*	No

Table 2: SIROM F characteristics

2.2.3 SIROM Family G

Lastly, SIROM G unifies versions E and F in a single unit, providing both electrical connection and a fluidic interface. Given the extended functionality, the power transfer shall be lower than SIROM E, especially when the fluid transfer is on-going.

SIROM G passive and active versions are shown in Figure 6. Family G characteristics are shown in Table 3.

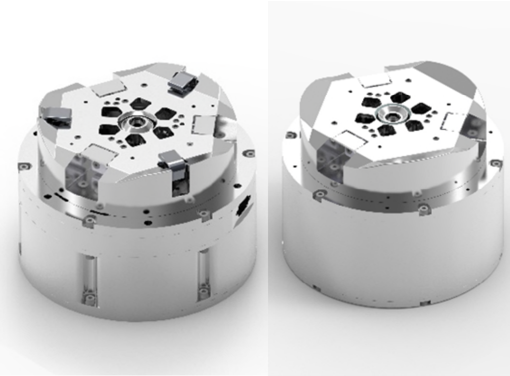

Figure 6: SIROM G (Active and Passive)

Therefore, the characteristics are a mixture between both versions. The fluidic interface is the same as SIROM F, while the connectors plate is identical as SIROM E.

The communication buses available are CAN bus and Ethernet, for low and high-speed data rate respectively. The power transfer is limited to low-consumption payloads, reserving high-power applications for SIROM E.

Similar to SIROM F, the fluidic connector goes through the mechanism, and therefore the only option is having external electronics. This unit is the same as SIROM E and F versions.

SIROM’s fluid connector is a compact solution that can withstand high-pressure while maintaining leak tightness. It is composed of an active and passive side. The transfer of fluids is performed through probes enclosed by sleeves. For the connection, the sleeve on the active SIROM retracts the sleeve on the passive SIROM. A chamber isolated by seals is created between both probes once the mating is completed.

SIROM G Active		SIROM G Passive	
Mass	1.6 kg	*Mass*	0.7 kg
Height	102 mm	*Height*	109 mm
Electronics	External	*Electronics*	No

Table 3: SIROM G characteristics

2.3 Refuelling interface validation

For the development of the SIROM F and G versions, the fluid connector has been the most challenging addition at this stage of development. For the past two years, the design and validation of the refuelling interface has been one of the focus areas in the design process.

The fluid connector has heritage from RIDER, a SENER project [6]. The existing design was modified to be accommodated within the SIROM volume, adapting the necessary elements to maintain the rest of the functionality.

The preliminary design was manufactured as a prototype to validate the connection between active and passive sides. This assembly was carried out in 2023, with preliminary latching tests that provided useful insight to guide the design. From these tests, the decision was taken to split the operation in two phases (latching/connectors deployment) with independent actuators, since the alternative was too complex to be reliable in harsh environments and extended lifetimes.

At the moment, additional tests are under design for the fluid connector validation prior its integration on the SIROM. On one hand, at component level several seals will be characterized in terms of insertion force and leakage. These tests are foreseen for the end of 2023 and will provide insight on the optimal seal selection.

On the other hand, the fluid connector will be manufactured to validate active and passive sides mating under different conditions of misalignment. After that, the connector will be submitted to leakage and pressure drop tests. .

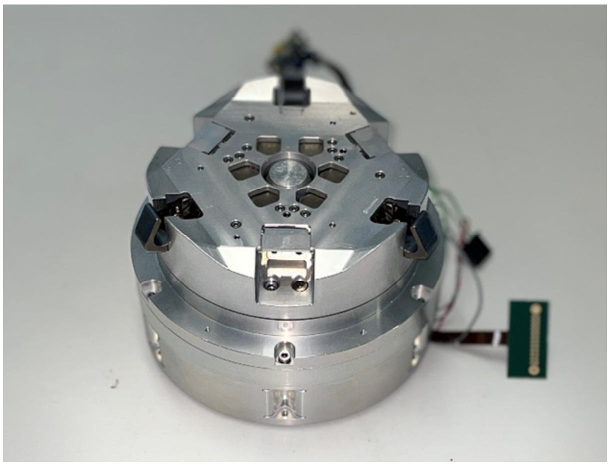

Figure 7: SIROM E prototype for validation

2.4 Flight adaptation

In all three families, one of the aims has been to prepare the design for flight applications. This entails different modifications that have been implemented across all families, which are reviewed in this section.

2.4.1 ESD and dust cover

As it has been mentioned in the previous section, in order to be able to produce a flight model, the exposed pins in the connectors plate needed to be guarded in the model to prevent Electrostatic Discharge (ESD). Therefore, an ESD cover was implemented in the design.

This cover is present in versions E and G; version F does not have electrical connection.

2.4.2 *Actuator*

As it has been already mentioned, a second actuator has been added to the design, identical to the first one.

However, to comply with space quality standards, both actuators had to be upgraded. The redesign mechanism is more demanding in terms of torque, so a more powerful actuator is needed in new families. EM versions include Maxon 3-phase BLDC actuator with a planetary gear reductor, very similar to the one used in SIROM C that obtained positive results.

For the space version, the approach for the SIROM product is to follow NewSpace philosophy. Hence, neither the motor coils nor the electronic boards have redundant sections, since the redundancy should be at spacecraft level. However, modifications have been made in the actuator to increase the reliability of the product itself.

Between the EM and FM versions, the improvements include: using vacuum compatible lubrication for the motor and the gearbox, corrosion resistant stainless steel for all gear teeth, hardened motor for shock environments, and space compatible hall sensors. The FM actuator will be from Maxon to maintain heritage between models.

2.4.3 *EEE for electronic subsystem*

From SIROM C, the electronic subsystem has been completely redesigned in terms of EEE selection. The previous version had EEE from military heritage, which were suited for demanding environments but did not have any information regarding radiation.

In the redesign, the EEE selection has been focused on have radiation tolerant components or automotive quality with available radiation tests information. For this purpose, the strategy has been unified with other NewSpace projects in SENER to create a Preferred Part List. This reduces the costs by unifying the EEE across several projects, so that extra costs such as additional qualification tests are shared.

One of the major changes in the electronics is the aforementioned upgrade of the microcontroller, but it also includes the motor drivers, the communications transceivers, acquisition circuits, and the new power supply block. The majority of the circuits remain mostly the same as previous versions, and the design with the upgraded EEE has already been validated with a prototype.

2.4.4 *External electronic unit*

As it was already discussed in previous sections, for SIROM families F and G the electronic subsystem is placed in an external electronic unit, as well as optionally for SIROM E.

This is forced due to the constraints of the refuelling design; however, it also allows the electronic subsystem to be in a different environment than the mechanism, which could be less harsh in order to protect the EEE from radiation (Total Ionizing Dose) and extreme temperatures.

Additionally, the external electronic unit has been designed to be modular and easily scalable, using a Cubesat-like approach with stackable Printed Circuit Boards. Using this concept, a considerable number of SIROM Electronic boards could fit in a single box, using a single CAN bus for commands and one bus for power supply. In case an additional board is needed (like power electronics or small payloads), it could be designed to be also placed in the stack, reducing volume and costs.

This format of the electronic subsystem will be implemented in both EROSS-IOD and ORU-BOAS projects (explained in section 3), with SIROMs from families E and G.

2.4.5 *Docking simulations*

In the theoretical plane, the capture range capabilities of the SIROM interface for docking has been studied using geometrical information and simulation analysis. The idea behind the study is to evaluate if the method of capturing the passive side using high-capture range latches and alignment petals is feasible for hard docking applications, apart from the tried and tested berthing between payloads or spacecraft to payloads.

In terms of design, the inclusion of proximity sensors in the top side of the interface is intended as an aid to docking operations. However, the information reliability depends on the sensor’s threshold, the selected magnet, and the relative position between the two sides. For this reason, a docking simulation analysis has been made using ADAMS software including dynamic behaviour as well as static positions [7].

The results of this analysis will be compared to the functional tests performed in the context of ORU-BOAS at DLR facilities, foreseen for 2024.

3 ON-GOING PROJECTS

The redesign of SIROM for the new families has been carried out in parallel to on-going projects, which will be briefly described in this section. The concurrent work has proven useful, since it provided valuable insight into the design added functionalities from a stakeholder perspective. The on-going projects are mainly EROSS-IOD, ORU-BOAS and ISAAC, shown in the roadmap in .

3.1 EROSS-IOD

EROSS-IOD is led by Thales Alenia France, as a continuation of the work started in H2020 OG7 EROSS (European Robotic Orbital Support Services) [1]. Phases B/C started in 2023 to reach TRL 6 at the end of 2024, with an in-orbit demonstration foreseen for 2026.

The purpose of EROSS-IOD is to demonstrate a complete orbital rendezvous of a servicer satellite and a collaborative client satellite. After the rendezvous, the capture and servicing operations take place, using SIs such as SIROM.

Two different SIROMs are being considered: a SIROM Family E integrated with its own electronics, and a SIROM Family G for a refuelling demonstration. The Orbital Replacement Unit (ORU), which will be transferred between Client and Servicer satellite, will be an outcome of ORU-BOAS, a SENER led project that is being developed in parallel.

3.2 ORU-BOAS

ORU-BOAS is a new development led by SENER Aeroespacial which aims at producing a common structure based on modular building blocks for commercial satellites. The interconnection of the blocks is done through SIs for power, data and fluid transfer.

The scope of the project is to reach TRL 4 for a modular structure based on COTS, including Data Handling System, Power System, Thermal Control System, and Standard Interfaces as common blocks. The prototype will be tested with two payloads to demonstrate the capability of adapting to different purposes. The prototype will be tested functionally and in a docking demonstration with a commercial robotic arm.

In parallel, along with the objectives of EROSS-IOD, ORU-BOAS shall provide a TRL 6 ORU for the current phase of EROSS-IOD, that will be later developed for a flight model. This ORU will be a reduced version to demonstrate the basic functionalities regarding SIs and power and data transfer.

The consortium is composed of European companies including Thales Alenia France, Thales Alenia Italy, ISISpace, EASN and Sener Aeroespacial. ORU-BOAS has started in 2023 with a 2-year development plan.

3.3 ISAAC

Following the line of work done in MIRROR [3], ISAAC (In-Space Assembly And Construction Technologies) proposes the assembly of large structures in space, using an autonomous robot for this purpose. ISAAC is led by Airbus Ltd, and the consortium includes Airbus SAS and GmbH, Magellium, Cranfield University and Sener Aeroespacial.

The involvement of the SIROM is used as a way to connect ORUs to the truss structure which will be built in-space. As a conceptual level, it is meant to demonstrate the mission using electrical and refuelling SIROMs. For the validation, a breadboard is foreseen for Q4 2024 to test the mission concept.

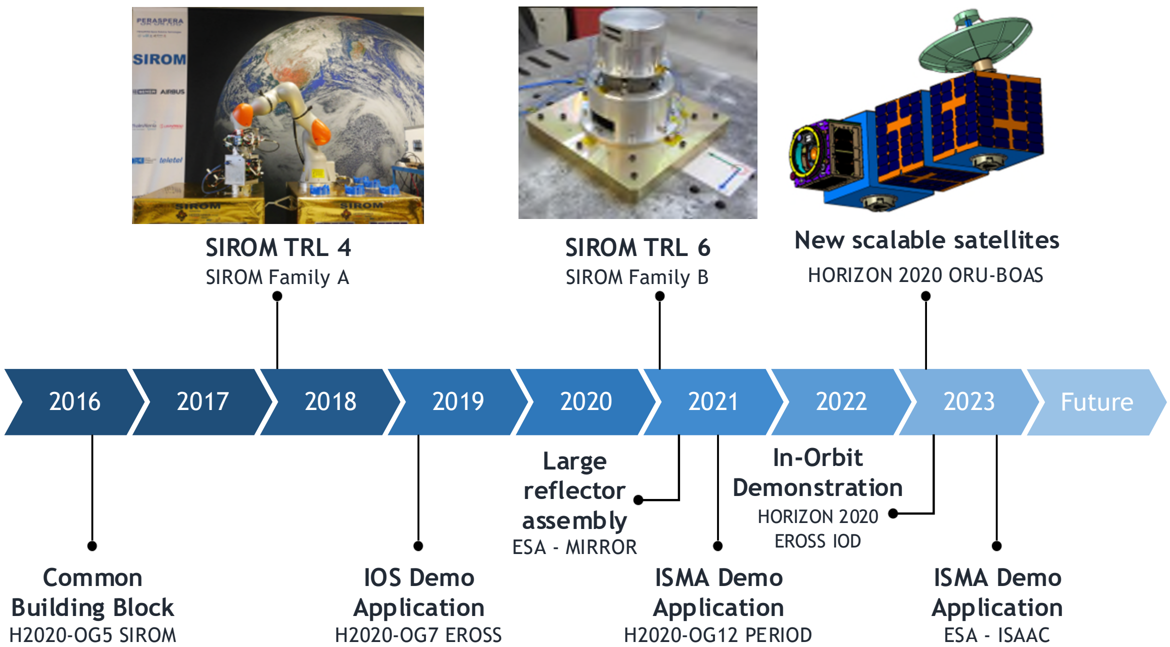

Figure 8: SIROM projects roadmap

4 CONCLUSION

In the past two years of SIROM development, several improvements have been made towards the adaptation of the product for future in-orbit applications. The design has been optimized with the aim of grouping common elements in three new SIROM families (E, F and G) that will allow an easier manufacturing process and lower production costs.

In parallel to the design process, SIROM is present in different European projects for IOS and ISMA applications. The involvement in such projects provides valuable insight from stakeholders which helps to create a more complete product for a wider range of missions. Some of the future projects in the roadmap include EROSS IOD, ORU-BOAS and ISAAC, which have all started in 2023.

In conclusion, SENER's solution for Standard Interfaces in the context of European Space Robotic missions is an on-going development that is advancing towards an in-orbit demonstration in the near future, establishing the product as a necessary building block for In-Orbit Servicing and In-Space Manufacturing and Assembly applications.

ACKNOWLEDMENTS

SENER has been or is actively involved in the following projects founded by the European Commission improving and seeking the adoption of SIROM as standard interface:

- EROSS under grant agreement Nº 821904.
- PERIOD under grant agreement Nº 101004151.
- EROSS-IOD under grant agreement Nº 101082464.
- ORU-BOAS under grant agreement Nº 101082078.

REFERENCES

[1] V. Dubanchet, J. A. Béjar Romero, K. N. Gregertsen, H. Austad, J. Gancet, K. Natusiewicz, J. Viñals, G. Guerra, G. Rekleitis, I. Paraskevas, K. Nanos, E. Papadopoulos, L. Majewski, S. Ferraris, J. Purnell, D. Casu, J. D'Amico y S. Andiappane, «EROSS project–European Autonomous Robotic Vehicle for on-orbit servicing,» de *International Symposium on Artificial Intelligence, Robotics and Automation in Space,(i-SAIRAS'20)*, Pasadena, California, USA, 2020.

[2] S. Estable, A. Ampe, A. Chamos, G. Aridon, D. Silveira, F. J. Colmenero Lechuga, I. Soto, J. Gancet, M. Shilton, M. Jankovic y T. Vogel, «PERIOD – PERASPERA In-Orbit Demonstration toward the transition into the in-space services, assembly and manufacturing paradigm,» *IOP Conference Series: Materials Science and Engineering,* vol. 1226, nº 1, p. 012095, 2022.

[3] J. Estremera, J. García, P. Romeo, A. Rodríguez, I. Colmenarejo, M. Lucia, M. Rusconi, G. Sangiovanni, S. Cordasco, D. Antonucci, A. Margan, L. Baccielliere, N. G. Tsagarakis, J. Viñals, G. Guerra y L. Gerdes, «Re-locatable manipulator for on-orbit assembly and servicing,» de *16th Symposium on advanced space technologies in robotics and automation (ASTRA)*, Noordwijk, 2022.

[4] J. Viñals, J. Gala y G. Guerra, «Standard Interface for Robotic Manipulation (SIROM): SRC H2020 OG5 Final Results-Future Upgrades and Applications,» de *i-SAIRAS*, Virtual Conference, 2020.

[5] M. Díaz-Carrasco Díaz, G. Guerra, J. Gala y J. J. Viñals, «Standard Interface for Robotic Manipulation (SIROM): Current state and future developments for one the main building blocks for space robotics advancement,» de *Proceedings of 72nd International Astronautical Congress (IAC)*, Dubai (United Arab Emirates), 25-29 October 2021.

[6] G. Guerra, J. Viñals, I. Soto, M. Diaz-Carrasco y J. Gala, «Development of a robotic Fluid Transfer interface based on RIDER connector,» de *16th Symposium on advanced space technologies in robotics and automation (ASTRA)*, Noordwijk, 2022.

[7] A. Lázaro y J. J. Viñals, «Mathematical modelling, simulation, test, and correlation of a capture before contact docking mechanism,» de *20th European Space Mechanisms and Tribology symposium (ESMATS)*, Warsaw, Poland, 20-22 September 2023.