FLEX Payload Interface Guide

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FLEX ROVER

Astrolab is developing the multi-functional Flexible Logistics & Exploration (FLEX) rover to support human operations, robotic science, exploration, logistics, construction, resource utilization, and other activities critical to enabling a sustained human presence on the Moon, Mars, and beyond.

Figure 1: The FLEX Rover terrestrial prototype.

About this guide

This guide provides details on the design and capability of our existing terrestrial rover prototype. The specific capabilities of our Lunar rover are still in development, but they are likely to meet or exceed the capabilities described herein. This guide is intended as a starting point for discussion with potential payload partners.

The mechanical interfaces, electrical interfaces, and size constraints required to design and develop a FLEX payload are introduced here. If you are interested in flight opportunities, analog testing, ground-based demonstrations, co-development of payloads, operations concepts, relevant proposal efforts, Earth applications, or investment please reach out to development@astrolab.space

Introduction

NASA and private industry investments will soon make it possible to land hundreds of tons on the Moon and Mars each month. Astrolab is developing the multi-functional Flexible Logistics & Exploration (FLEX) rover with this burgeoning environment in mind. The FLEX rover's unique commercial potential comes from its novel mobility system architecture, which gives it the ability to pick up and deposit modular payloads in support of human operations, robotic science, exploration, logistics, site survey/preparation, construction, resource utilization, and other activities critical to a sustained presence on the Moon and beyond.

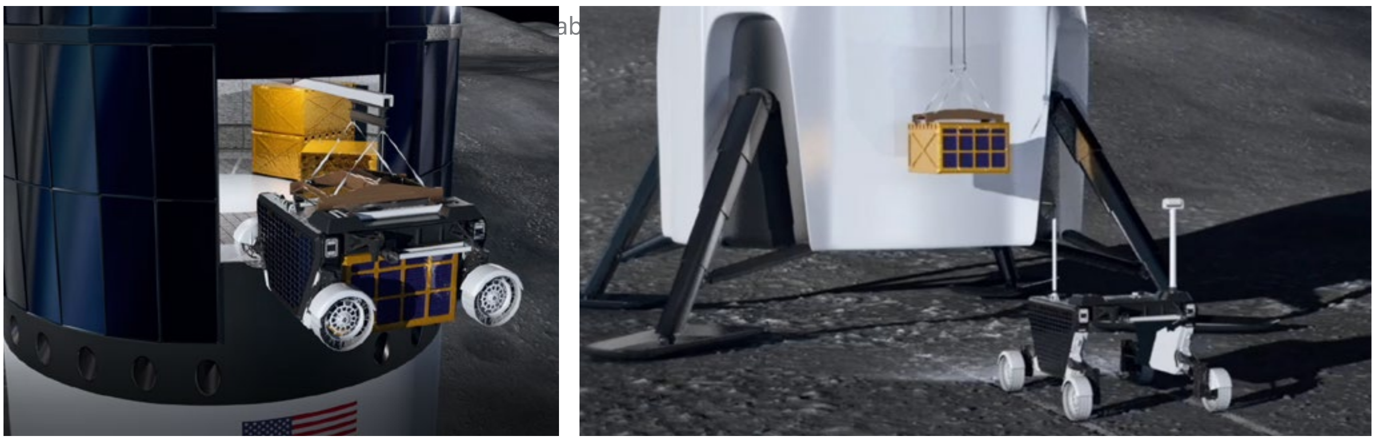


Figure 2: The Astrolab intermodal payload standard provides the ability for a single lander to deliver many payloads that a FLEX rover can transport.

For humanity to truly live and operate in a sustainable way off Earth, there needs to exist an efficient and economical transportation network all the way from the launch pad to the ultimate outpost. There is currently a gap in the "last mile" of this transportation network, and FLEX is specifically designed to fill it. We envision a near-future in which large commercial landers laden with dozens of payloads will land on the Moon and Mars with high cadence. The FLEX rover is designed to be easily deployed from these landers and subsequently support the unloading and distribution of all the other landed payloads (Figure 2, also see our animation here for the concept of operations).

Astrolab has developed and tested a full-scale terrestrial proof-of-concept FLEX Rover and is inviting government, academic, and commercial entities to partner with us in the design and field testing of payload concepts. Our desire is to foster a community of payload developers that are adhering to an open and standardized interface. We believe this will ultimately lead to a vibrant off-Earth economy, in much the same way that intermodal standardized payload containers have become the lifeblood of global trade.

FLEX Flexible Logistics & Exploration

FLEX represents the first fully commercial approach to rover design. Historically, planetary rovers have each been bespoke and have been put into operation on a timescale of roughly once per decade. Having been custom-designed around a particular payload, they can each cost billions to develop and qualify. This approach is not compatible with NASA's ultimate goal of supporting a sustained presence on the Moon and Mars. To improve this situation and to spur the development of a vibrant off-Earth economy, we have designed FLEX around a modular payload interface that supports intermodal transportation (from lander to rover and back).

FLEX can accommodate payloads with volumes in excess of 3m^3 and as much as 1,000kg in mass. Multiple rovers can also collaborate to move even larger payloads (e.g., for lander relocation or outpost construction). Our rover can support human operations, teleoperated/semi-autonomous science, exploration, logistics, site survey/preparation/construction, and other activities (Figure 3) critical to a sustained presence on the Moon and beyond.

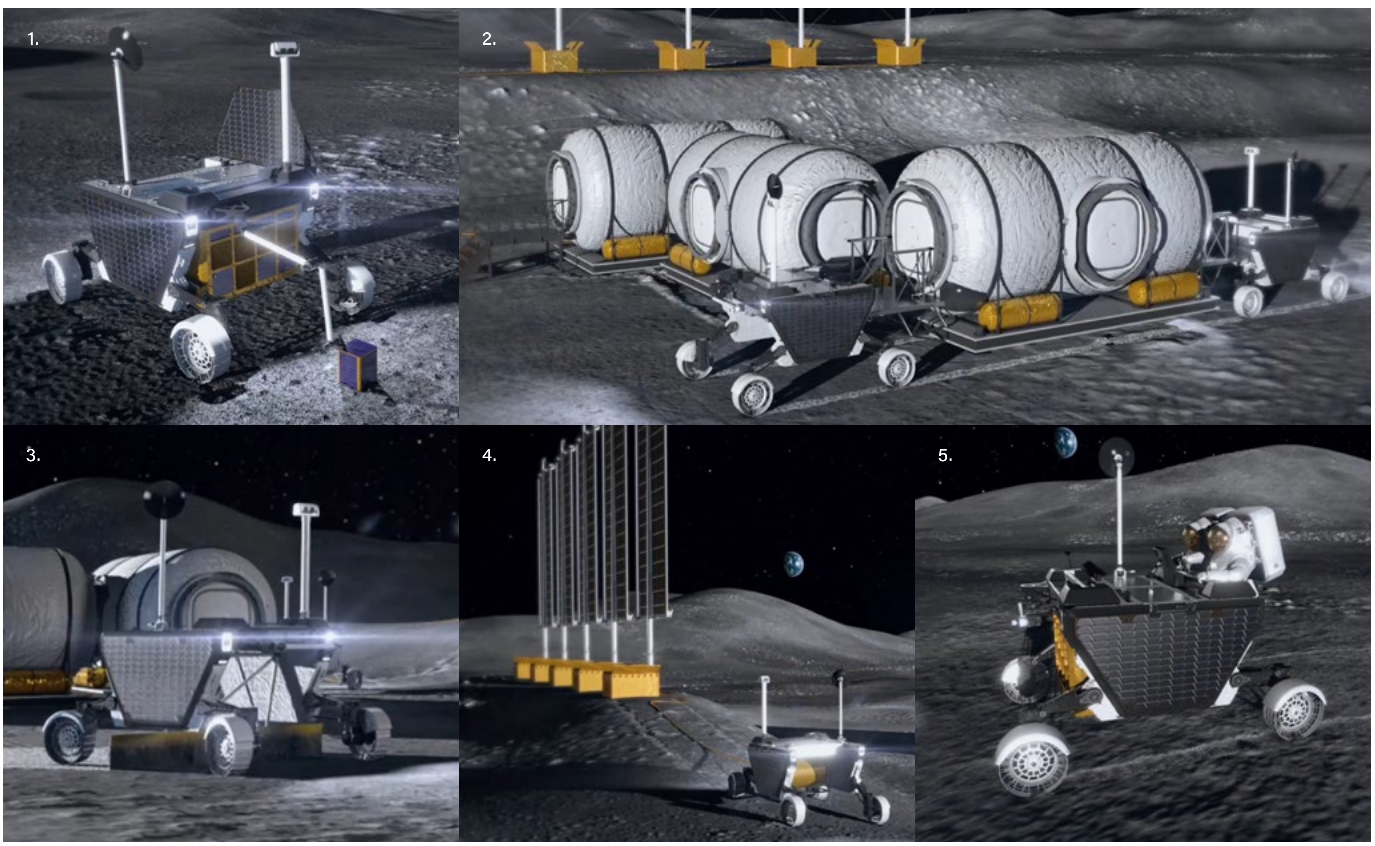


Figure 3: FLEX's modular payload interface and novel mobility system enable it to perform a multitude of functions, including 1. Distributed science; 2. Coordinated multi-rover manipulation of large payloads to support outpost construction; 3. Regolith grading and excavation; 4. Surface power and transmission cable deployment; and 5. Crew transport and exploration.

FLEX features a novel wheel-on-limb mobility system that can raise and lower the chassis ground clearance and adapt to variable terrain while maintaining stability. This system also lets the rover lower attached instruments and equipment to the ground and/or independently collect and deploy modular payloads (Figure 4). The vehicle features a dust-tolerant quick disconnect interface, including blind mate umbilicals that connect to a myriad of payloads. The umbilicals are used to supply payloads with regulated electrical power, data connections, and thermal management services as required.

Figure 4: FLEX's innovative wheel-on-limb system allows the rover to retrieve, transport, and deploy payloads that conform to common interface standards. Examples include: 1. Outpost Logistics; 2. Crew Rescue 3. Marsupial Rover, 4. Cable Spool, 5. Vertical Solar Array Tower, 6. Crew EVA Equipment.

FLEX also features a six-degree-of-freedom (6DOF) robotic arm with payload capability exceeding 25kg (250N) within a 2m radius workspace. With this FLEX can deploy multiple smaller payloads, including payloads that require precise placement or additional interaction in the form of mechanical or electrical power. The robotic arm also includes a modular end effector with interfaces designed for a wide variety of use cases.

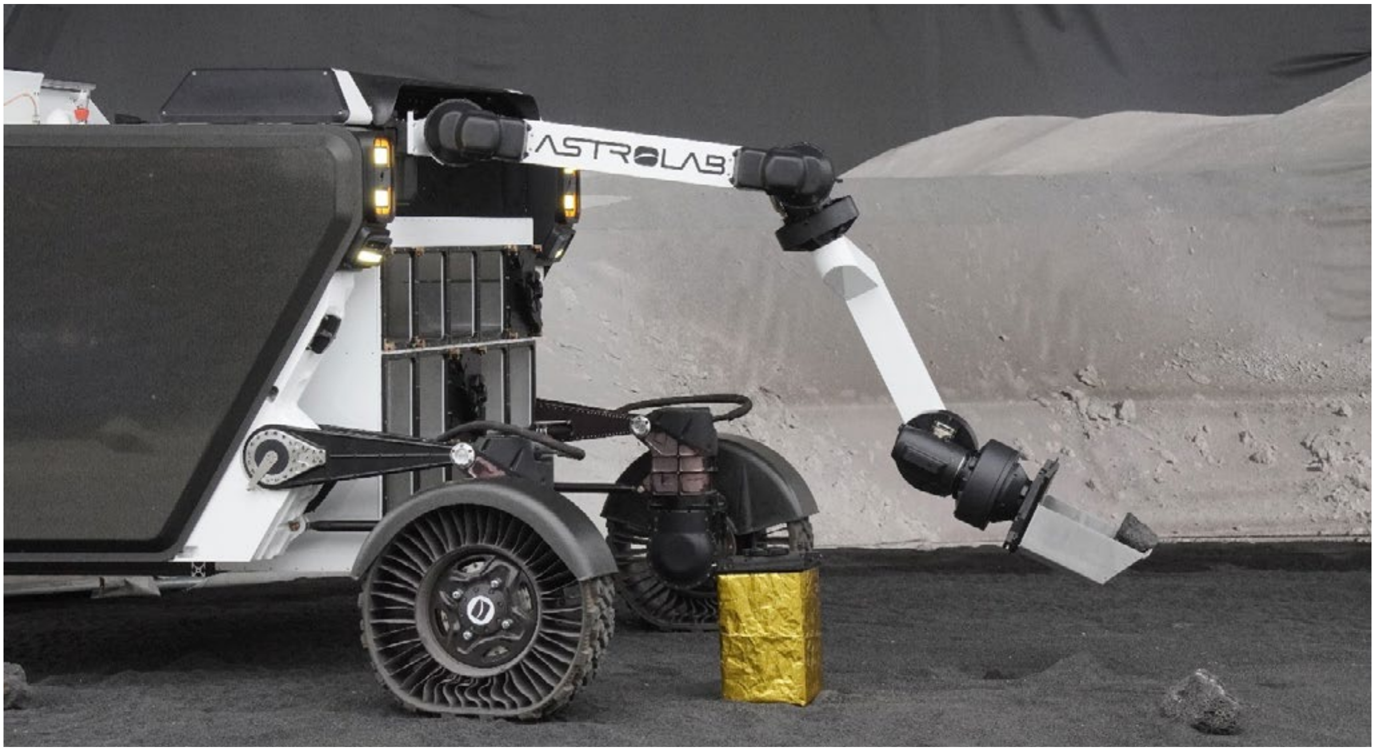


Figure 5: FLEX's 2m robotic arm has a modular end effector to add extensive functionality to the vehicle. The assembly is shown above with a sample collection scoop configuration after deployment of a payload with a 12U cubesat form factor.

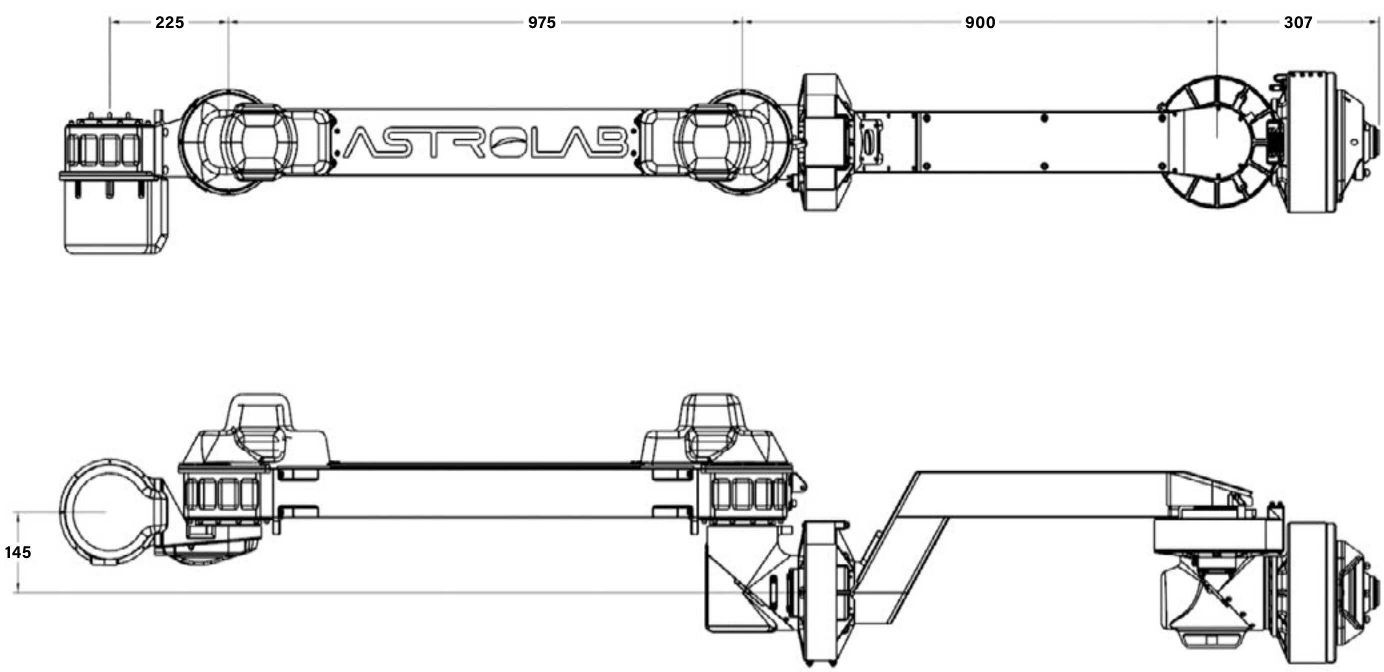


Figure 6: FLEX robotic arm dimensional layout.

Payload Interface Definition

Astrolab aims to advance the common definition of Lunar cargo interfaces by specifying standardized mating features for both underslung and top-deck payloads. Modular FLEX payloads conform to standard mechanical and electrical interfaces, defined here for the Terrestrial prototype. Please contact Astrolab at development@astrolab.space for further design information or for customized payload requirements.

The FLEX rover can accommodate cargo attached to both the underside and top side of its chassis (Figure 5). The rover is capable of robotically docking to payloads at each of the three interfaces (two on top & one below). The quick disconnect interfaces allow for payloads to be loaded, transported, and then unloaded at a different location.

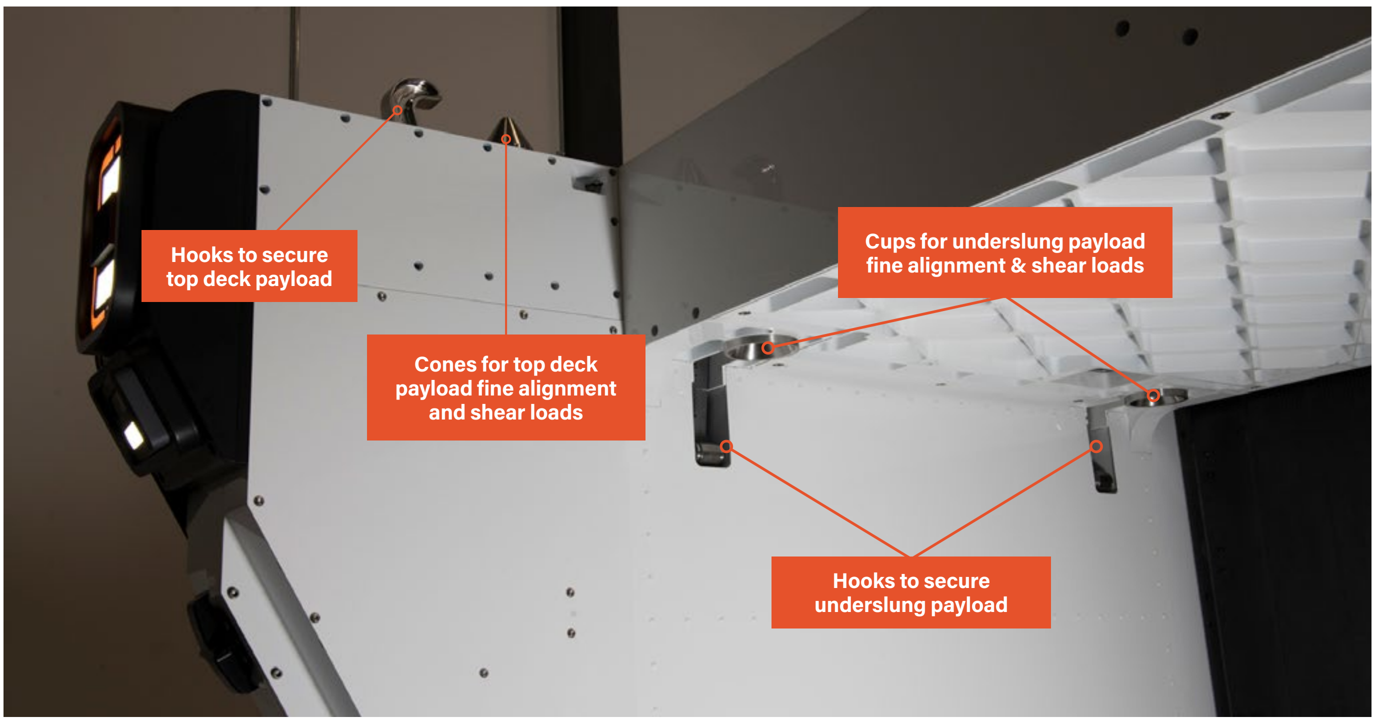


Figure 7: FLEX has two top-deck payload interfaces and one underslung payload interface.

Top-deck and underslung payload accommodations are designed to provide the payload owner with generous volume and design flexibility. The FLEX architecture allows for multiple vehicle configurations, a sample of which are illustrated below (Figure 6 through Figure 10), by joining top-deck payloads with underslung cargo containers of three standard sizes. Payloads may also utilize multiple interfaces and span top-deck and underslung payload envelopes, provided they are compatible with vehicle operation and keep-out zones. The vehicle's modular design allows interchangeability of payloads and configurations over the lifetime of a mission.

The below keep-in volumes are intended to be illustrative and payloads with non-conformal geometry can likely be accommodated.

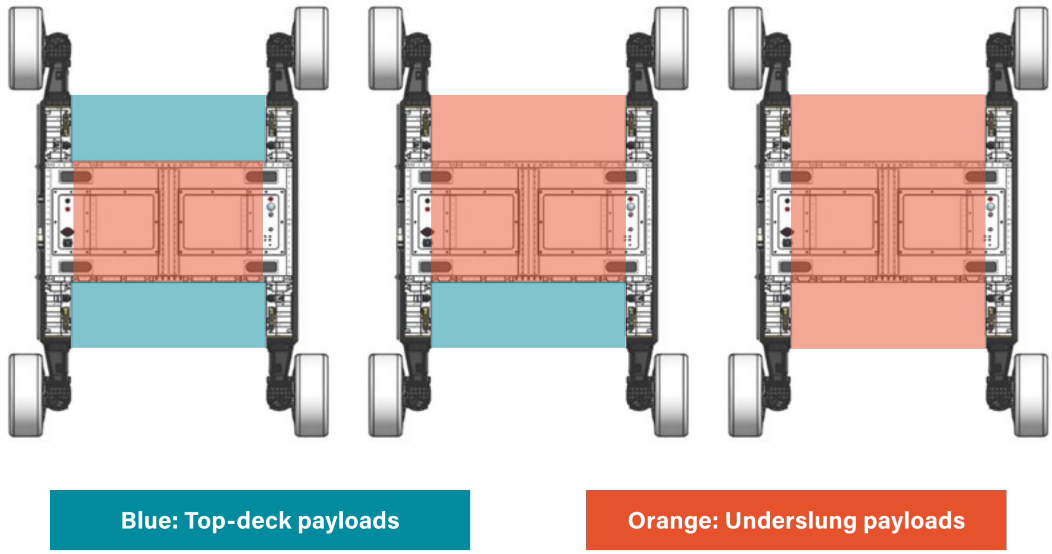
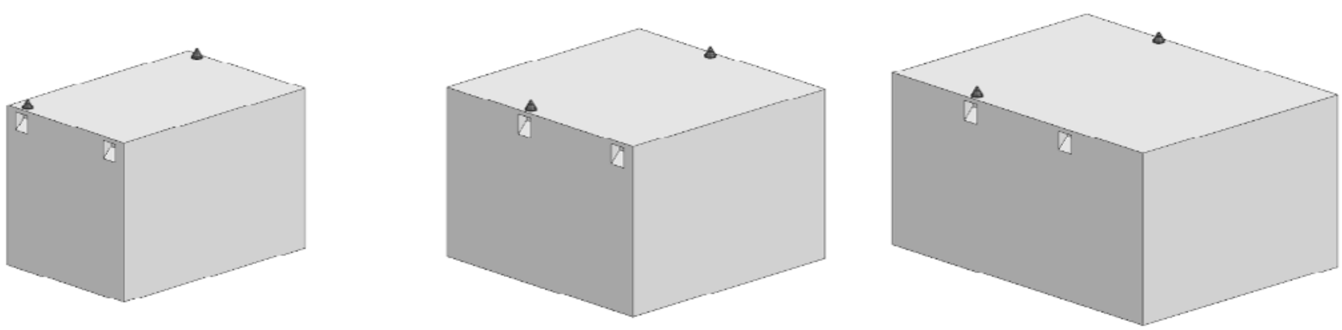
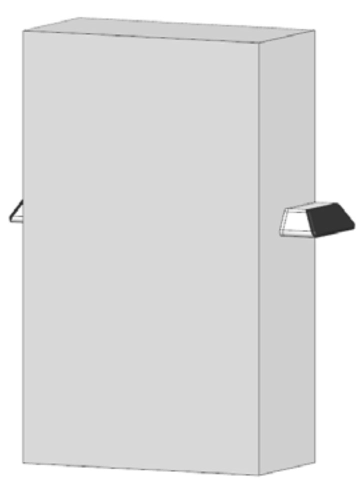


Figure 8: Top-view illustration of select FLEX payload configurations.



1.5 x 1.0 x 1.0 m **1.5 x 1.5 x 1.0 m** **1.5 x 2.0 x 1.0 m**

Figure 9: Underslung payloads: Overall dimensions of standard-size cargo containers.



1.5 x 0.75 x 2.5 m

Figure 10: Top-deck payload: Overall dimensions of payload design envelope.

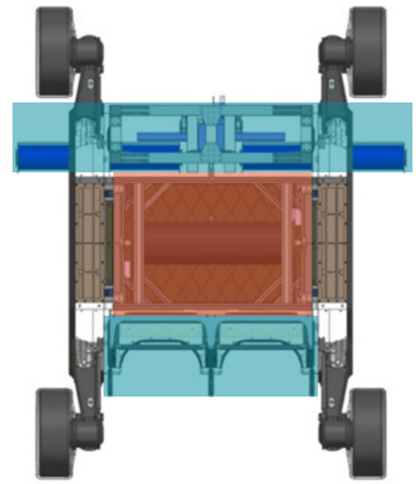
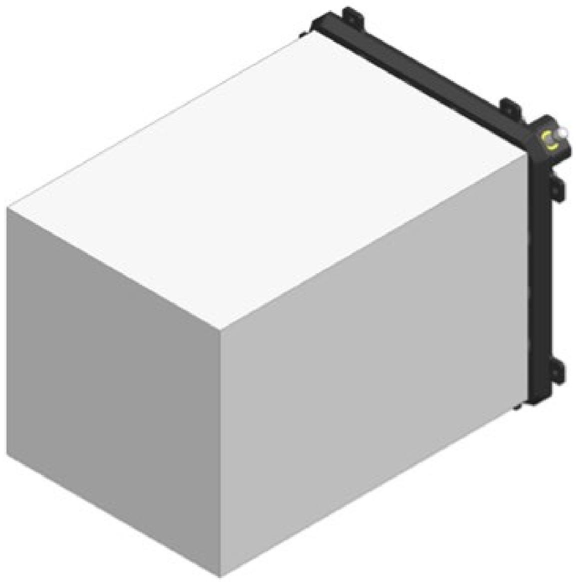


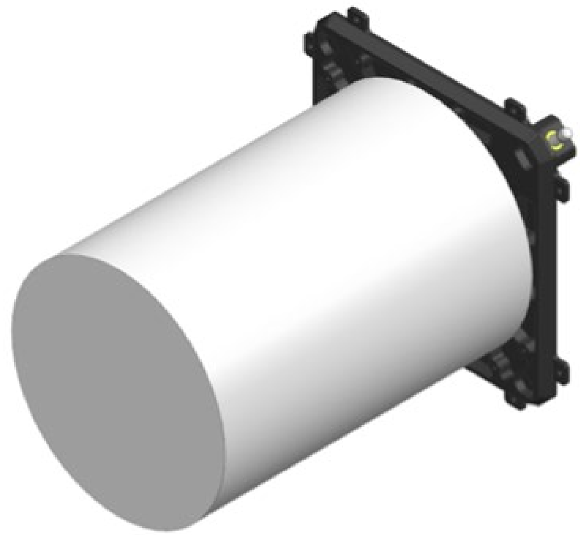
Figure 11: Example Terrestrial prototype configuration: Crew deck and vertical solar array tower top-deck payloads with 1.0 m standard-size underslung cargo.

Figure 12: Field test deployment of a vertical solar array tower (a top-deck payload) and cable spool (an underslung payload). The rover's removeable crew interface is another example of a top-deck payload.

FLEX's robotic arm accommodates payloads or tools of varying form factors and can interact with larger underslung or top deck payloads as required. Astrolab has also developed a modular payload storage rack capable of holding up to 15 individual end effector attachments and/or payloads with a form factor as large as a 12U-cubesat. Adapter hardware is available from Astrolab to facilitate rapid development of test articles.



236 x 236 x 340.5 mm



236 x 340.5 mm

Figure 13: Overall dimension limits of standard robotic arm payloads: torque transmitting (right) and static mounting (left).

The robotic arm is capable of expanded volumes and higher loads depending on the specifics of the design in question. Please contact development@astrolab.space for further design information or for customized payload inquiries.

Estimated load limits and lift capability (terrestrial prototype):

The chassis of the FLEX terrestrial prototype is designed to support the loads shown in the figures below. Estimates can be used as general guidance in sizing of payloads for co-development and terrestrial testing.

Specification of load and mass limits for the Lunar vehicle is in progress. As size and mass allowance are comparable, similar load limits with higher mass limits are expected for operation in Lunar gravity. Please contact Astrolab at development@astrolab.space for payload development inquiries, customized requirements, or information on Lunar payload definition.

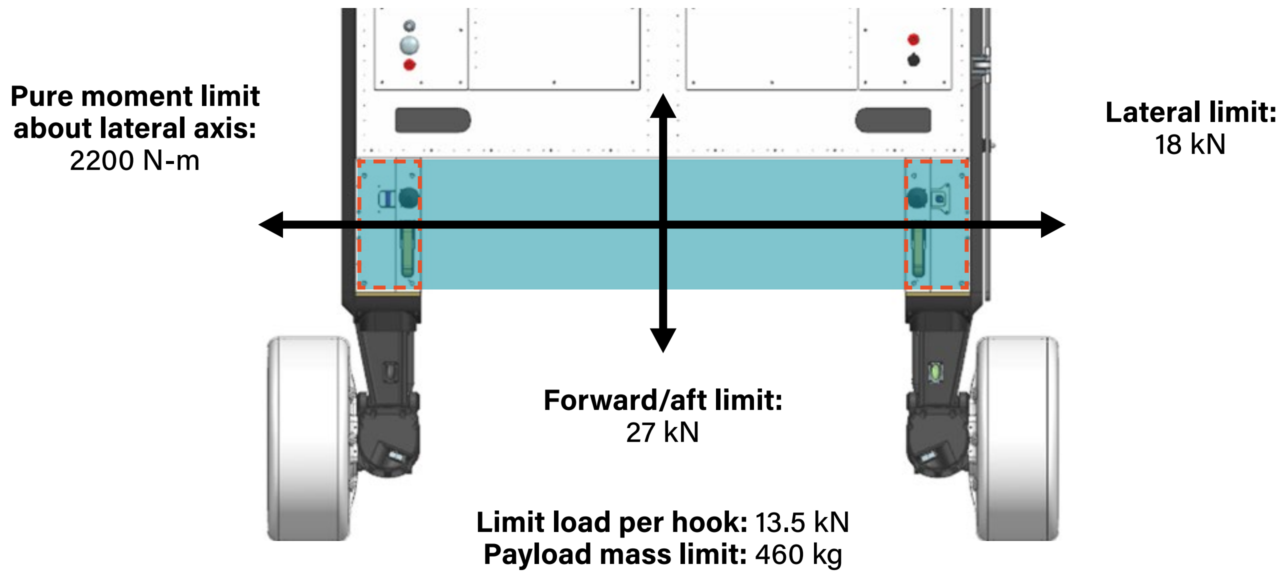


Figure 14: Top deck payload interface design limits.

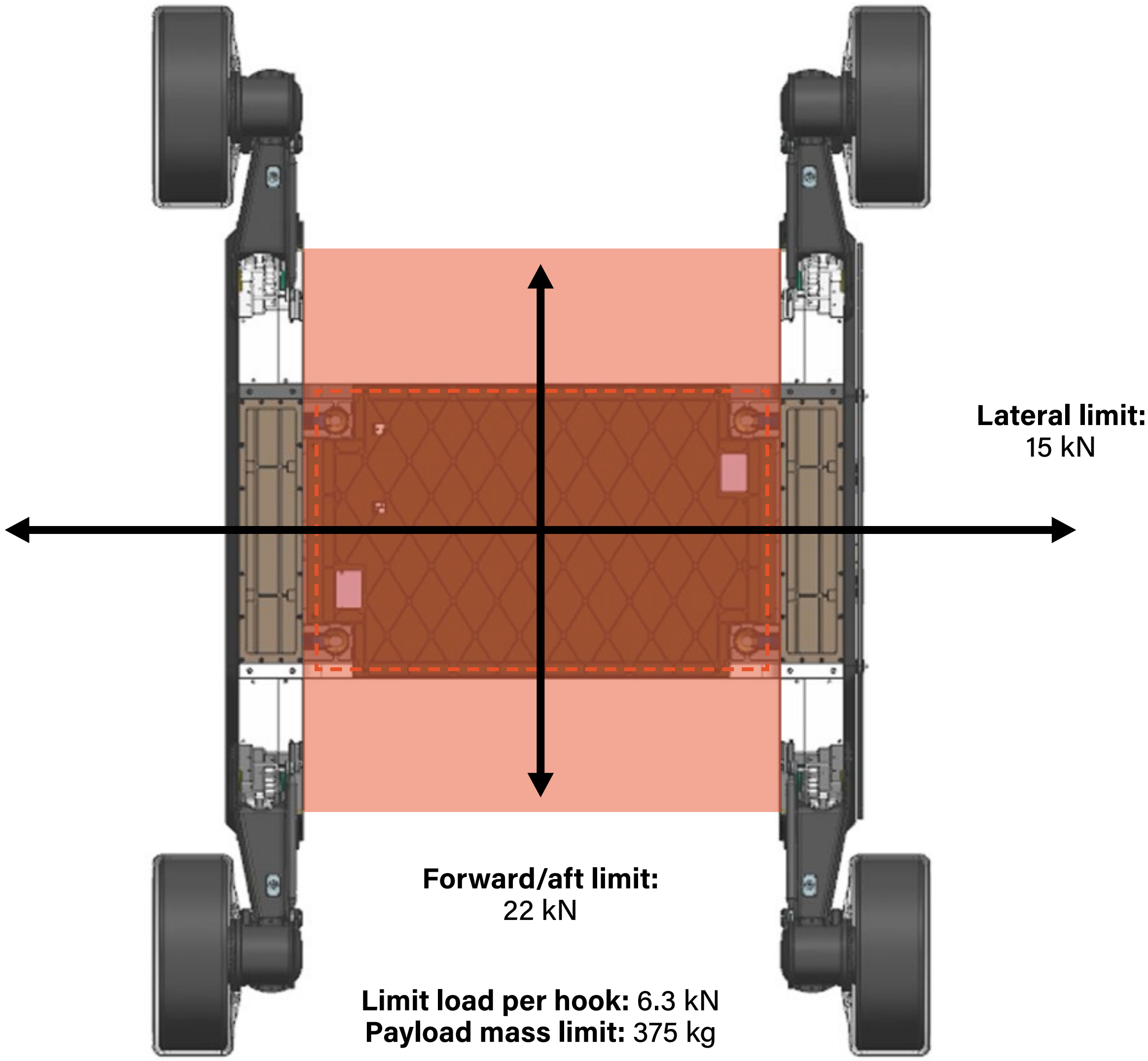


Figure 15: Underslung payload interface design limits.

The robotic arm payload capabilities listed below are provided as guidelines for preliminary sizing of components and order-of-magnitude capabilities. As mentioned previously, the operational envelope may be expanded to allow for unique payloads and test objectives.

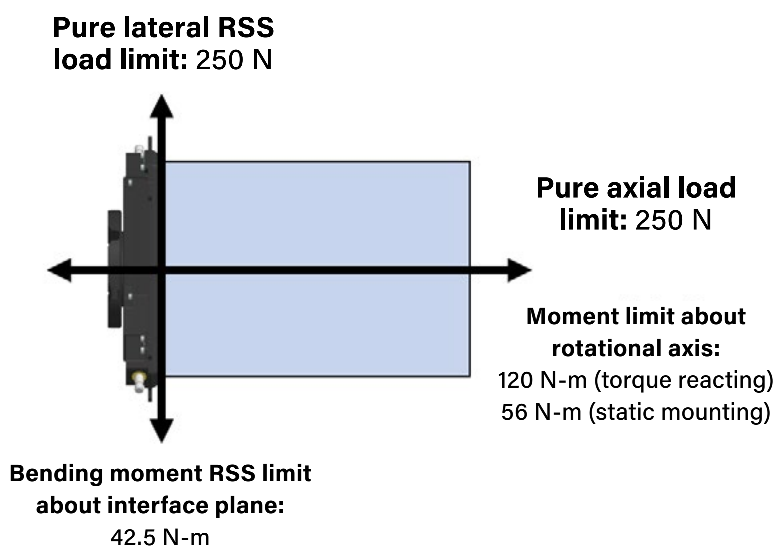


Figure 16: Robotic arm load limits for preliminary design.

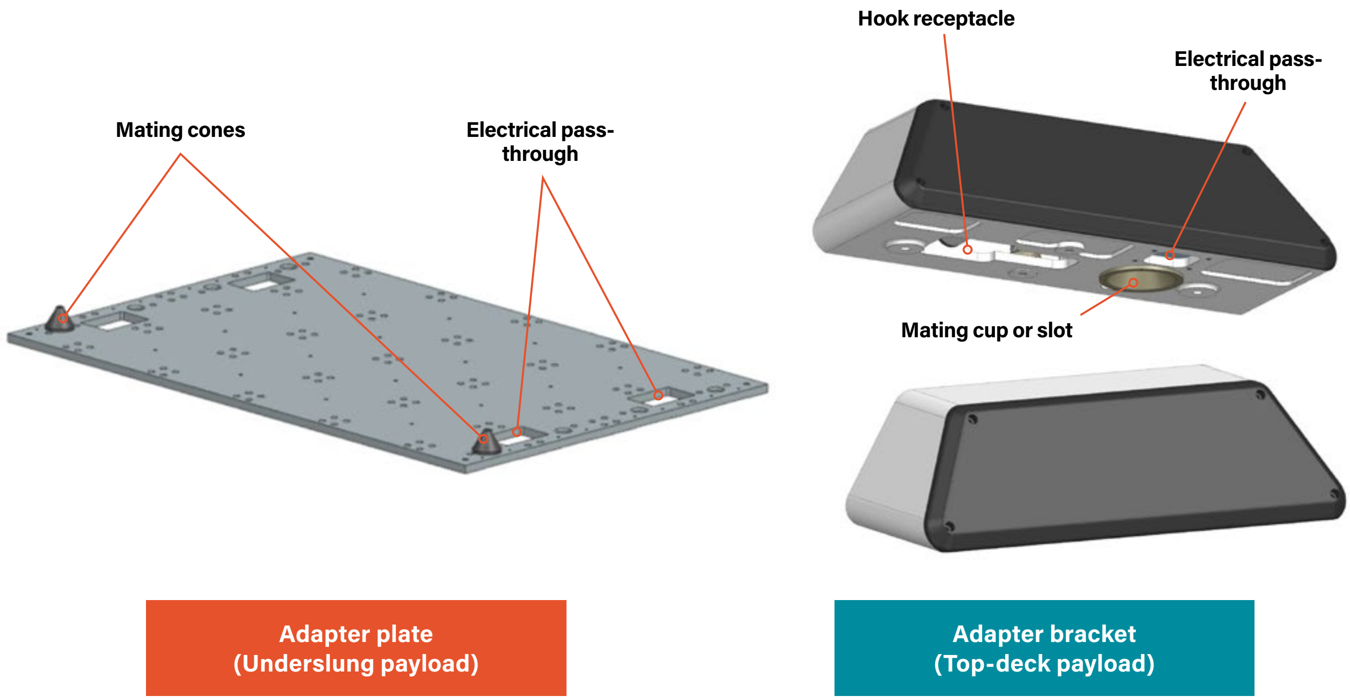


Figure 17: Mechanical adapters for underslung payload (left) and top-deck payload (right).

Mechanical interface definition (terrestrial prototype):

FLEX's modular design offers standardized mating interfaces for top-deck and underslung payloads. Dimensions for the terrestrial prototype are available for download by clicking on the schematics below. Dimensioning for the following key mating features is provided:

- **A minimally constrained cup-cone interface**
- **Receptacles designed to engage the vehicle's mechanisms for latching and preloading**
- **Electrical pass-throughs for provision of power and communication between FLEX and payloads**
- **Envelope dimensions for each payload type**
- **Specification of mating interfaces for the Lunar vehicle is in progress and is expected to be comparable to the specifications shown.**

To facilitate rapid and compliant payload design, Astrolab offers a mechanical adapter for each payload type. The adapters are intended to allow government, academic, and commercial partners to quickly prototype and field test novel payloads or operations concepts. Adapter plates are available for underslung payloads, and pairs of adapter brackets are available for top-deck payloads. Both items are included in the schematics and are designed to interface with payload designs via a regular bolt pattern. Larger top-deck payloads can be accommodated by making use of both top-deck interfaces.

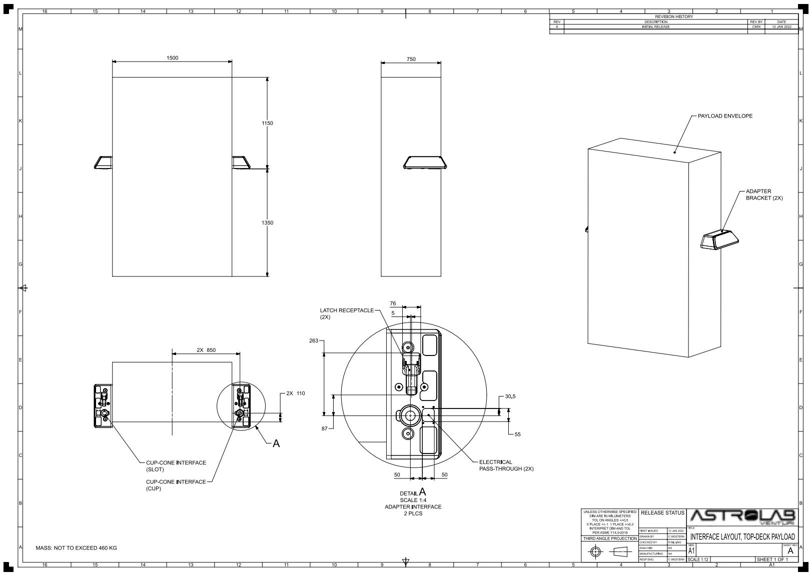


Figure 18: Top-deck payload and interface specification. (Click to download)

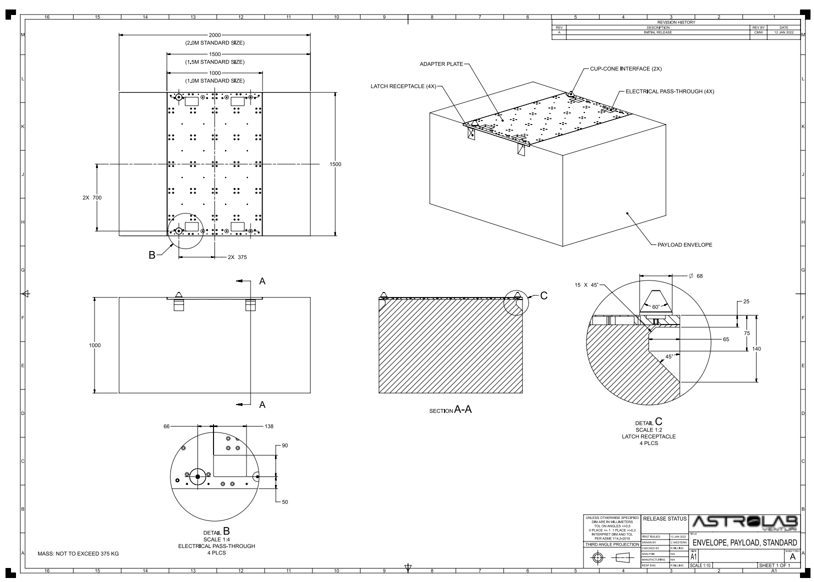


Figure 19: Underslung payload and interface specification. (Click to download)

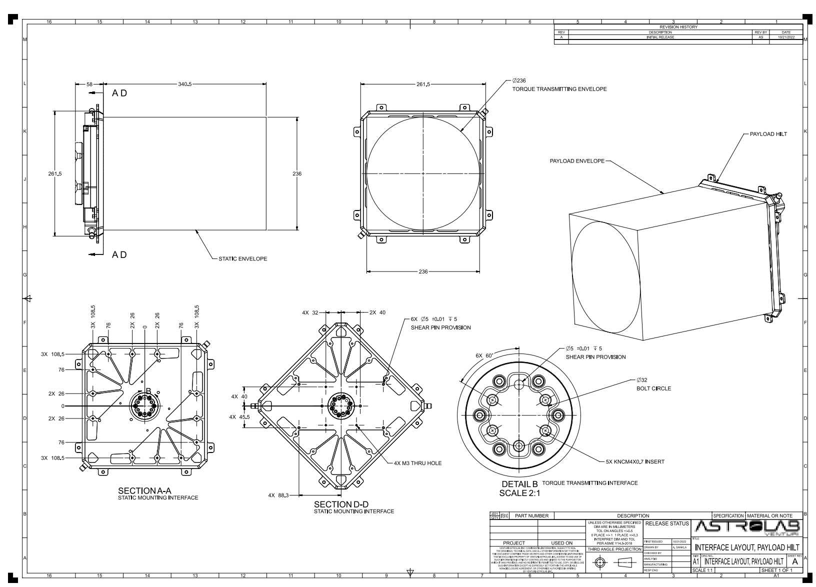


Figure 20: Robotic arm payload adapter specification. (Click to download)

Please contact Astrolab at development@astrolab.space for payload development inquiries, customized requirements, mechanical adapter needs, or information on Lunar payload definition.

Electrical and control interface definition (terrestrial prototype):

FLEX provides payloads with logic and bus power by means of blind-mate umbilicals located at the electrical pass-throughs at each payload interface (two top deck, one underslung, one robotic arm). FLEX also provides communication links for payloads with telemetry reporting or onboard computing.

Power and communication provisions offered by the terrestrial prototype for each payload are summarized in the table below. Estimates for the Lunar design are in development. As specifications are dependent on vehicle configuration, please contact Astrolab at development@astrolab.space for questions or customized requirements.

	BUS VOLTAGE	MAXIMUM POWER CONSUMPTION (STANDARD PAYLOAD)	MAXIMUM POWER CONSUMPTION (ROBOTIC ARM PAYLOAD)
Low-voltage power:	24 V DC (Regulated)	100 W	25W
High-voltage power:	60 – 80 V DC (Unregulated)	750W	100W
Communication:		Gigabit Ethernet	

Software:

The FLEX rover uses a flexible architecture with significant flight heritage for its primary flight software. Based on proven software used on a multitude of NASA missions, the system provides a portable, reusable, and modular solution to expedite spacecraft development. The architecture abstracts vehicle operations allowing customer payloads as much or as little control of the rover as necessary to support the payload objectives. Please contact Astrolab at development@astrolab.space for questions or customized requirements.

The rover's supervised autonomy functionality (autonomous hazard avoidance and navigation to operator-selected waypoints) runs independently and is integrated into the core flight systems via a software bridge. This approach simplifies expansion and modification of the autonomous functions, including the ability to shift some functions to ground-based assets (to optimize development schedule or mitigate risk). The FLEX API architecture is ideal for collaboration between the multiple institutions working on autonomy related to the various payloads under development. Our software is rigorously verified with unit testing, physics-based simulation in the loop testing, hardware in the loop testing, and full-system integration testing.

Field Testing:

Astrolab has a strong culture of fast design, build, and test iteration. Field testing in analog environments is an essential part of our development process. We have therefore invested in infrastructure to get our rover and your payload out of the lab and into the field with ease. If you have a payload idea and would like to participate in one of our upcoming field tests, please reach out to development@astrolab.space.

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