

The 500-Gram Insurance Policy for PWSA Satellites

An SDA-class spacecraft compatibility study for Astroscale's Docking Plate.



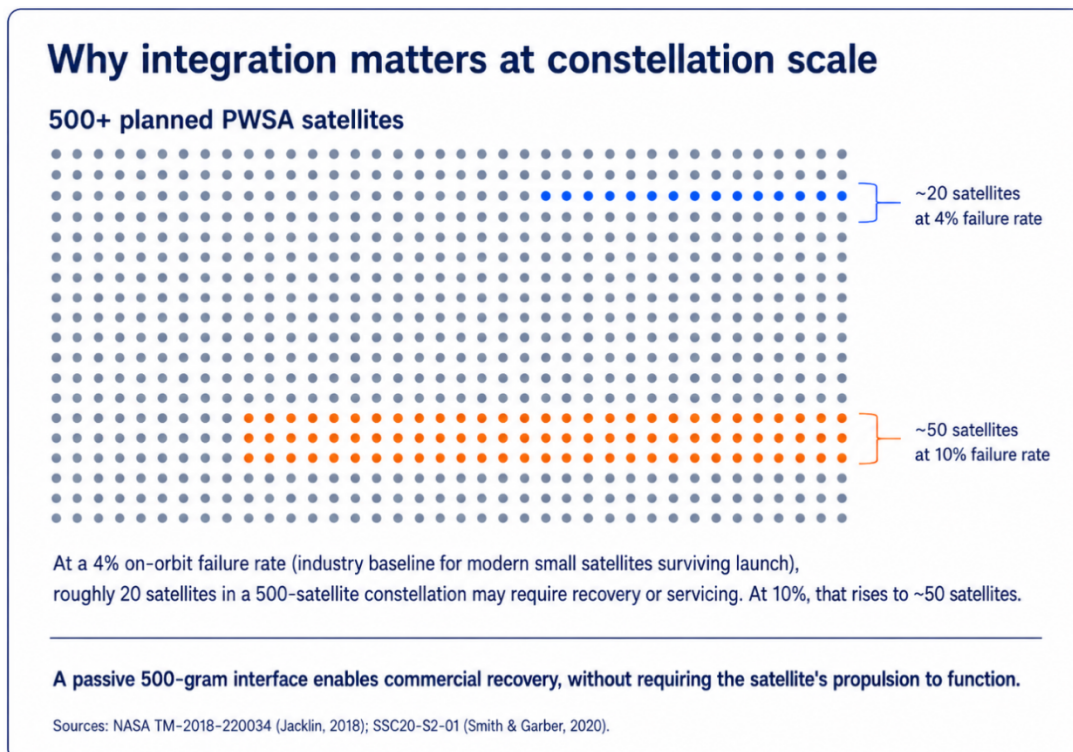
1.0 Introduction

This paper assesses the integration impact of a passive docking interface on an SDA-class spacecraft bus. Astroscale's Docking Plate, at a little less than 500g, is approximately 0.4% of typical payload mass margin, with no power or internal volume requirements, while enabling compliance with emerging deorbit and servicing requirements while providing an architecture resilient to failure.

A note on the scope. This is a concept level feasibility study, the early-stage analysis that confirms whether an integration is technically viable before detailed design work begins using Astroscale's Docking Plate specifications and a synthetic SDA-class reference bus generated by Lyra to represent an ESPA-Grande spacecraft bus. It identifies the constraints that drive bus design and flags items requiring deeper analysis (FEM, CFD, mass properties) as the design matures during preliminary design or later in the program lifecycle.

2.0 Why This Matters

- **Regulatory pressure is real and rising.** The FCC's 2024 5-year post-mission deorbit rule, updated U.S. Orbital Debris Mitigation Standard Practices, and the ESA Zero Debris Charter are pulling debris mitigation into the technical baseline of every defense and civil RFP.
- **SDA is buying De-Orbit as a Service (DaaS).** Over \$54M in DaaS contracts awarded to date, plus an open Direct-to-Phase-II SBIR funding "design recommendations for future Proliferated Warfighter Space Architecture (PWSA) spacecraft that improve serviceability and reduce integration friction with DaaS providers." Future tranches will expect DaaS compatibility.
- **Proliferated architecture means proliferated debris risk.** Hundreds of PWSA satellites across Transport, Tracking, and Custody layers means even a small propulsion failure rate creates a meaningful debris population. A single debris remediation mission costs tens of millions of dollars today.
- **Acquisition advantage today, not retrofitting tomorrow.** A pre-integrated docking plate is a one-line proposal addition that demonstrates design maturity, debris mitigation thinking, and lifecycle awareness, at a fraction of the cost of redesigning a flight-proven bus to add docking compatibility after the fact.



3.0 The Hardware Enabler: Astroscale's Docking Plate



Figure 1 Astroscale's Docking Plate

Astroscale's Docking Plate is a passive mechanical interface that lets a servicer capture a satellite for deorbit, refueling, or repositioning. It is qualified and flight-proven.

The plate is servicer-agnostic. The interface supports magnetic and robotic capture and aligns with CONFERS and Space Safety Coalition standards. This makes integrating a docking plate an investment in shared infrastructure rather than vendor lock-in. The Docking Plate supports three distinct capture methods (magnetic, mechanical wrap, and clasp), which provides servicer-agnostic choice and CONOPS flexibility.

Specification	Value
Top plate diameter	150 mm
Top Deck Assembly thickness	15 mm
Leg height options	70 mm, 120 mm, 165 mm
Mass	400 to 500 grams (varies with leg option)
On-orbit lifetime	15+ years
Mechanical interface	3x M5 bolts, late AIT integration compatible
Navigation aids	Multi-range Aruco fiducial markers
Capture options	Magnetic, mechanical wrap, clasp
Power required	0 W (passive)
Flight heritage	TRL 9 with several commercial and government customers.

A note on hardware-agnostic servicers. Some servicers, including Starfish Space's Otter are designed to dock with unprepared client surfaces and do not require a docking plate at all. This is a complementary approach rather than a competing one: a bus with a docking plate remains accessible to unprepared-surface servicers while also being accessible to the prepared-interface servicer ecosystem. The docking plate adds servicer options without removing any. For risk-sensitive procurement today, the prepared-interface path also carries the advantage of flight heritage and a defined, qualified capture envelope.

4.0 Reference Bus

The compatibility analysis below evaluates integration of the docking plate against a representative SDA-class spacecraft model. Rather than using a specific flight platform, the study uses a synthetic “reference bus” constructed to reflect typical proliferated LEO mission requirements. The reference bus is based on an ESPA-Grande class spacecraft, including optical crosslinks, Ka-band downlink, and Hall Effect propulsion, and is representative of a mid-sized PWSA satellite. PWSA Tracking Layer buses are larger given their payloads, so typically have even greater payload margin available to embark a docking plate.

5.0 Integration Results and Considerations

The docking plate is designed for minimal integration burden. Lyra ran a holistic, concept level integration analysis against the SDA-class reference bus. The table below shows structured checks across mass, power, volume, mechanical, magnetic, thermal, structural, and capture-dynamics dimensions. Items requiring further validation at preliminary design phase or later are explicitly identified and summarized in the table below.



Figure 2 Illustrative render of the docking plate integrated on a synthetic SDA-class reference bus. The plate is mounted at the geometric center of the anti-velocity face with its Y-axis aligned with the bus center of gravity. The gimbaled Hall thruster is mounted off-center on the same face. Bus geometry is representative, not a specific flight design.

Domain	Checks Performed	Lyra Finding
Mass and power	0.5 kg against 120 kg payload margin; 0W passive	0.4% of margin, no power impact
Mechanical envelope	150 mm diameter footprint on 1040 x 1120 mm face; 3x M5 bolt pattern to M6 insert grid; 50g aluminum adapter	1.6% of face area; standard interface

Placement and stability	Centered on anti-velocity face, Y-axis through bus CG; height moment 0.114 kg·m (medium leg)	Primary placement verified; lateral offset and stiffness verify at PDR
Environmental qualification	Thermal qualified -135°C to +145°C; vibration qualified 14.1/20 Grms	Exceeds typical LEO and launch environments
Electromagnetic and Optical	Magnetometer on boom, torque rods on +Y/-Y; star trackers on +Z/+Y/-Y	All stay-out zones clear, no FOV conflicts
Capture dynamics	310 kg client mass within ELSA-M capture envelope; gimbaled Hall thruster plume clearance	Within margin; plume clearance verifies at PDR

The integration impact is small. The docking plate consumes 0.4% of the bus payload mass margin, draws no power, occupies no internal volume, and uses 1.6% of the anti-velocity face. It is qualified beyond typical LEO and ESPA-class launch environments. The mechanical interface requires a 50-gram aluminum adapter plate. Magnetic and sensor stay-out zones are clear. Capture loads sit within the bus structural margins for a ~300 kg client mass paired with an ELSA-M class servicer.

Three items mature as the bus design progresses. Lateral CG offset depends on final mounting placement and CG migration over the mission lifetime. First-mode stiffness for the long-leg variant requires FEM verification against launch vehicle minimums. Thruster plume clearance is verified for the gimbal's full range of motion using bus-specific plume geometry. None of this is novel engineering, and Astroscale's user guide provides the detailed thresholds and procedures bus designers use for these analyses.

The compatibility analysis above applies a structured integration methodology, assessing all relevant dimensions at a concept level design and identifying items that depend on bus-specific design decisions. This approach enables early identification of integration constraints and reduces the risk of late-stage design changes during AIT or operations.

6.0 CG, Moment and Placement Methodology

The docking plate location drives both bus mass properties and post-capture controllability. Astroscale's integration guidelines flag four placement considerations.

6.1 Y-axis alignment with bus CG (primary). The plate's Y-axis (perpendicular to the capture face) should align with the bus center of gravity. When aligned, the servicer's contact force passes through the bus CG and minimizes tip torque during capture. X/Z misalignment is the dominant concern, since a lever arm between the plate Y-axis and the bus CG can impart a tip the servicer must then overcome.

For the reference bus, this places the plate at the geometric center of the anti-velocity face with the gimbaled Hall thruster relocated to a corner. CG migrates as Hall thruster

propellant is consumed, so later design phases verify residual offset stays within Astroscale's load envelope across the mission lifetime.

6.2 Y-axis standoff (secondary). The distance from the bus CG to the capture face produces wobble transients during capture: shorter legs reduce wobble, longer legs trade wobble margin for servicer clearance.

6.3 Assembly Heights. Using a 100 mm adapter offset assumption (Lyra's default for separation plane to bus deck), the assembly heights are:

Leg Option	Plate/2	Leg	Adapter	h_{CG} / Moment (0.5 kg)
Short (70 mm)	7.5 mm	70 mm	100 mm	178 mm / 0.089 kg·m
Medium (120 mm)	7.5 mm	120 mm	100 mm	228 mm / 0.114 kg·m
Long (165 mm)	7.5 mm	165 mm	100 mm	273 mm / 0.136 kg·m

Height moment contributions in this range are small for ESPA-class moment budgets. Capture-phase wobble is governed by Astroscale's load profiles.

6.3 Moment of Inertia. Low MOI risks "bounce-off" during capture; high MOI makes the mated stack sluggish post-capture. The 310 kg reference bus falls in the middle of the capture-friendly MOI range.

6.4 First-mode stiffness. The plate-on-truss assembly is a cantilever during launch. Launch vehicle minima are typically above 25 Hz; the long-leg variant has the lowest first-mode frequency and is verified by FEM at later design stages.

7.0 NRE: What Does Integration Cost?

Integration in early design phases is the lowest-cost path. The docking plate is designed for late AIT installation (3 bolts, no propellant interfaces, no electrical interfaces), but the engineering analysis to enable that path is most efficiently done before PDR.

Design Phase	Estimated NRE	Driver
Concept (CoDR)	Minimal	Add to mass budget, allocate space, document. No analysis impact.

Design Phase	Estimated NRE	Driver
Preliminary (PDR)	Low	Adapter plate design, CG update, ICD inclusion, sensor FOV check.
Post-CDR	Medium	Update analyses, drawings, ICDs. May require customer approval for design change.
Flight-proven retrofit	High	Heritage changes trigger re-verification. Documentation effort dominates.

8.0 The Math

Item	Value
Docking plate mass + adapter (if needed)	~0.55 kg, 0.5% of payload margin
Docking plate power	0 W
Integration NRE at concept phase	Minimal

9.0 Conclusion

The integration impact of a docking interface in the 500g class is minimal. It represents approximately 0.4% of typical payload mass margin, requires no power or internal volume, and introduces a standard mechanical interface with minimal additional hardware. Integration considerations are confined to standard engineering checks, with a small number of items requiring verification at later design stages as spacecraft configurations mature.

As proliferated architectures scale (such as PWSA), the frequency of such integration assessments is expected to increase across components, payloads, and servicing interfaces. Efficient evaluation of these integrations at early design phases may reduce the risk of late-stage design changes and associated program impacts for spacecraft manufacturers and SDA stakeholders.

About This Analysis

This analysis evaluates docking interface compatibility across a representative SDA-class spacecraft configuration using a structured integration approach. The assessment covers multiple parameters spanning mass, power, volume, thermal, mechanical, magnetic, and structural constraints. The evaluation is performed using Lyra's AI and physics mission integration engine,

applied to a synthetic SDA-class reference bus from Lyra's library. This approach enables consistent assessment across multiple integration dimensions at an early stage of spacecraft design.

The results presented reflect concept design level integration analysis, identifying integration constraints and areas requiring further verification at later design stages. The reference bus and component assumptions are intended to be representative rather than exhaustive; results may vary depending on specific spacecraft configurations and mission requirements. This is Mission 1 of the 100 Missions Project. Lyra is producing 100 mission architecture studies demonstrating how AI accelerates mission integration.