AI Review Report

Paper: Soft Inflatable Robotic Systems for Space Applications: A Survey

Paper ID: 23

Review Service: Reviewer3.com

Generated: June 22, 2026 at 17:02 UTC

Round 1 - Completed

Paper version: v1

Submitted: May 15, 2026 at 15:03 UTC

Completed: May 15, 2026 at 15:14 UTC

reviewer3

The manuscript appears to conflate the numerical value of angular momentum with kinetic energy to justify the fragmentation risk. While a 1000 kg upper stage tumbling at 5 deg/s (0.087 rad/s) may indeed have an angular momentum of approximately 50 N m s (assuming an appropriate moment of inertia), its total rotational kinetic energy would be less than 5 Joules. It is physically impossible for a rigid grasp to concentrate "50 J of despin energy" into a hinge when the total kinetic energy of the tumbling system is an order of magnitude lower. This fundamental physics error invalidates the subsequent application of the 10 J/g IMPACT model threshold and must be corrected to provide an honest assessment of fragmentation probability.

reviewer1

The quantitative example used to demonstrate the fragmentation paradox contains a significant calculation error that undermines the subsequent claim about exceeding fragmentation thresholds. For a 100-kg object with a 0.5 m moment arm, the moment of inertia is at most 25 $kg \cdot m^2$ (assuming a point mass). An angular velocity of 5 deg/s is approximately 0.087 rad/s. The resulting rotational kinetic energy is approximately 0.095 Joules, not "several hundred joules" as stated in the text. It appears the authors calculated the energy using degrees per second directly instead of converting to radians per second. Consequently, the assertion that this interaction would yield a specific energy of 5 J/g on a 10 g fastener (which would require 50 Joules of energy transfer) is mathematically impossible under the stated parameters, invalidating this specific quantitative justification.

reviewer1

The authors state that mass per unit floor area (areal density) is equivalent to mass per unit pressurised volume (volumetric density). This is geometrically incorrect and obscures the primary physical advantage of inflatable structures. Due to the square-cube law, as a habitat's radius increases, its volume grows much faster than its surface area. Therefore, a constant areal density (kg/m^2) of the shell material will result in a decreasing volumetric density (kg/m^3) as the structure scales up. Treating these metrics as equivalent misrepresents the scaling laws that make large-volume inflatable habitats highly mass-efficient compared to rigid modules.

reviewer2

The manuscript presents a quantitative comparison of actuation technologies using a 0-10 rating scale across five performance dimensions. However, the text lacks a defined scoring rubric or methodology detailing how these numerical values were derived from the qualitative literature. Without explicit criteria for what constitutes a specific score (e.g., the quantitative thresholds for a '7' versus an '8' in bandwidth or mass efficiency), this assessment is subjective and cannot be reproduced. Please provide the specific quantitative thresholds or the detailed evaluation matrix used to assign these scores.

proof-verifier

The drag force values presented in Table 20 are inconsistent with the provided formula $F_D = \frac{1}{2} \rho v^2 C_D A$. At an altitude of 500 km, the orbital velocity is approximately $v \approx 7,616$ m/s. For the "Solar min, broadside" case ($\rho = 5 \times 10^{-13}$ kg/m^3, $A_{\text{eff}} = 5,000$ m^2, $C_D = 2.4$), the correct calculation yields $F_D = 0.5 \times (5 \times 10^{-13}) \times (7616)^2 \times 2.4 \times 5000 \approx 0.174$ N. The table lists 0.35 N, indicating the $1/2$ factor was omitted. Additionally, the "Solar max, broadside" row lists a force of 14 N. Since its density is 6 times higher and its C_D is $3.2/2.4 \approx 1.33$ times higher than the "Solar min, broadside" case, the force should scale by a factor of 8 (yielding $0.35 \times 8 = 2.8$ N if the $1/2$ is still omitted). The listed value of 14 N introduces an unexplained additional factor of 5.

reviewer2

Figure 11 presents continuous curves for drag force versus altitude under solar minimum and maximum conditions, which inherently rely on an underlying atmospheric density model. However, the specific atmospheric model used to generate these density profiles (such as NRLMSISE-00 or JB2008) is not identified in the text or figure caption. Please specify the atmospheric model and the exact solar activity indices used so that these computational results can be independently reproduced.

reviewer2

The manuscript presents drag force estimates in Table 20, but it omits the specific orbital velocity value used for these calculations. Because atmospheric relative velocity depends on assumptions regarding atmospheric co-rotation and exact orbital parameters, this missing parameter prevents readers from reproducing the force estimates. Please explicitly state the velocity value and any associated orbital assumptions used to generate the results in Table 20.

Round 2 - Approved

Paper version: v2

Submitted: May 15, 2026 at 16:43 UTC

Completed: May 15, 2026 at 16:43 UTC

Comment 1

Score: 4/4 - Fully addressed

Original comment:

The manuscript presents a quantitative comparison of actuation technologies using a 0-10 rating scale across five performance dimensions. However, the text lacks a defined scoring rubric or methodology detailing how these numerical values were derived from the qualitative literature. Without explicit criteria for what constitutes a specific score (e.g., the quantitative thresholds for a '7' versus an '8' in bandwidth or mass efficiency), this assessment is subjective and cannot be reproduced. Please provide the specific quantitative thresholds or the detailed evaluation matrix used to assign these scores.

Author response:

We agree that without an explicit rubric the 0?10 ratings are not reproducible. We have added a scoring rubric as a new table immediately preceding the figure, giving the quantitative threshold for each of the four bands (0?2, 3?5, 6?8, 9?10) across all five performance dimensions (Space TRL, force output, bandwidth, vacuum compatibility, mass efficiency). Intermediate scores within a band are assigned by interpolation or by engineering judgement where the literature reports qualitative rather than numerical performance; this is now stated explicitly in the rubric caption.

Reviewer assessment:

The author has fully addressed this concern by adding a new table (Table 15) that provides a detailed scoring rubric for the actuation technology comparison. This table clearly defines the quantitative thresholds for each score band across all five performance dimensions, making the assessment in Figure 9 transparent and reproducible. The addition of this table completely resolves the issue of subjectivity.

Comment 2

Score: 4/4 - Fully addressed

Original comment:

The manuscript presents drag force estimates in Table 20, but it omits the specific orbital velocity value used for these calculations. Because atmospheric relative velocity depends on assumptions regarding atmospheric co-rotation and exact orbital parameters, this missing parameter prevents readers from reproducing the force estimates. Please explicitly state the velocity value and any associated orbital assumptions used to generate the results in Table 20.

Author response:

Agreed. The velocity and co-rotation assumption are now stated explicitly in the Table 20 caption.

Reviewer assessment:

The author has fully addressed this comment by updating the caption for the relevant table (now Table 21 in the revised manuscript). The caption now explicitly states the assumed orbital velocity (7,616 m/s) and the assumption of a non-co-rotating atmosphere. This addition provides the necessary information for readers to reproduce the calculations.

Comment 3

Score: 4/4 - Fully addressed

Original comment:

Figure 11 presents continuous curves for drag force versus altitude under solar minimum and maximum conditions, which inherently rely on an underlying atmospheric density model. However, the specific atmospheric model used to generate these density profiles (such as NRLMSISE-00 or JB2008) is not identified in the text or figure caption. Please specify the atmospheric model and the exact solar activity indices used so that these computational results can be independently reproduced.

Author response:

The reviewer is correct that the original caption omitted both the model and the solar-activity indices. The figure uses representative NRLMSISE-00 500 km density anchors with exponential interpolation in altitude ? this is now fully disclosed. We chose disclosure of the simplified exponential interpolation over an NRLMSISE-00 lookup at every altitude because the interpolation is well within 15 % of NRLMSISE-00 across the 300?800 km range and is reproducible from the two anchor points and the scale heights given in the caption.

Reviewer assessment:

This comment has been fully addressed. The author has updated the caption for Figure 11 to specify that the curves are based on NRLMSISE-00 density anchors with exponential interpolation, and provides the scale heights used. The surrounding text and the caption for Table 21 now also include the specific solar activity indices (F10.7 values), making the analysis transparent and reproducible.

Comment 4

Score: 4/4 - Fully addressed

Original comment:

The quantitative example used to demonstrate the fragmentation paradox contains a significant calculation error that undermines the subsequent claim about exceeding fragmentation thresholds. For a 100-kg object with a 0.5 m moment arm, the moment of inertia is at most 25 $kg \cdot m^2$ (assuming a point mass). An angular velocity of 5 deg/s is approximately 0.087 rad/s. The resulting rotational kinetic energy is approximately 0.095 Joules, not "several hundred joules" as stated in the text. It appears the authors calculated the energy using degrees per second directly instead of converting to radians per second. Consequently, the assertion that this interaction would yield a specific energy of 5 J/g on a 10 g fastener (which would require 50 Joules of energy transfer) is mathematically impossible under the stated parameters, invalidating this specific quantitative justification.

Author response:

The reviewer is correct on both counts. The previous text treated 5 deg/s as if it were 5 rad/s and overstated rotational kinetic energy by a factor of approximately 3,300. The 5 J/g specific-energy estimate on a 10 g fastener was numerically impossible for a 100 kg target. We thank the reviewer for the careful arithmetic check and have rewritten the passage to be physically consistent.

Reviewer assessment:

The author has thoroughly corrected this major calculation error. The revised manuscript replaces the incorrect kinetic energy value with the correct one (0.095 J) and reframes the fragmentation argument for sub-tonne debris to be based on contact stress, which is more physically sound. The bulk-energy argument is now correctly applied only to larger, ENVISAT-class targets where the kinetic energy is significant (65 J). This thoughtful revision completely resolves the issue and strengthens the paper's argument.

Comment 5

Score: 4/4 - Fully addressed

Original comment:

The authors state that mass per unit floor area (areal density) is equivalent to mass per unit pressurised volume (volumetric density). This is geometrically incorrect and obscures the primary physical advantage of inflatable structures. Due to the square-cube law, as a habitat's radius increases, its volume grows much faster than its surface area. Therefore, a constant areal density (kg/m^2) of the shell material will result in a decreasing volumetric density (kg/m^3) as the structure scales up. Treating these metrics as equivalent misrepresents the scaling laws that make large-volume inflatable habitats highly mass-efficient compared to rigid modules.

Author response:

The reviewer is correct. The two metrics are geometrically distinct, and the square-cube argument is precisely the reason large inflatables become uniquely attractive ? we should have made the scaling explicit rather than collapsing the metrics. The corrected passage now derives the relationship explicitly and uses it to strengthen rather than weaken the inflatable-habitat case.

Reviewer assessment:

This comment is fully addressed. The author has rewritten the relevant paragraph in Section 2.2 to correctly distinguish between areal and volumetric density. The revised text now includes a clear explanation of the scaling relationship (?v = 3?/R), which correctly highlights the mass-efficiency advantage of large inflatable structures due to the square-cube law. The corresponding table has also been updated for clarity.

Comment 6

Score: 4/4 - Fully addressed

Original comment:

The manuscript appears to conflate the numerical value of angular momentum with kinetic energy to justify the fragmentation risk. While a 1000 kg upper stage tumbling at 5 deg/s (0.087 rad/s) may indeed have an angular momentum of approximately 50 N m s (assuming an appropriate moment of inertia), its total rotational kinetic energy would be less than 5 Joules. It is physically impossible for a rigid grasp to concentrate "50 J of despin energy" into a hinge when the total kinetic energy of the tumbling system is an order of magnitude lower. This fundamental physics error invalidates the subsequent application of the 10 J/g IMPACT model threshold and must be corrected to provide an honest assessment of fragmentation probability.

Author response:

The reviewer is correct, and this is the same underlying physics error identified by Reviewer 1 (R1.1) ? angular momentum (units N·m·s) was numerically equated with energy (units J). For a 1000 kg upper stage at 5 deg/s, total rotational kinetic energy is bounded below 5 J as the reviewer notes, making the previous ?50 J despin energy into a hinge? claim physically impossible. The bulk-energy framing at the 10 J/g IMPACT threshold is not defensible at the sub-tonne to single-tonne scale; the corrected text reserves that framing for ENVISAT-class (multi-tonne) targets where rotational kinetic energy is genuinely of order tens of joules or more, and anchors the small-target fragmentation argument on contact stress instead.

Reviewer assessment:

The author has fully addressed this fundamental physics error. The flawed example conflating angular momentum and energy has been removed from the revised manuscript. The entire section on fragmentation risk has been rewritten to be physically accurate, separating the analysis for small targets (now based on contact stress) from large targets (where a corrected bulk-energy analysis is appropriate). This correction is thorough and resolves the concern completely.

Comment 7

Score: 4/4 - Fully addressed

Original comment:

The drag force values presented in Table 20 are inconsistent with the provided formula $F_D = \frac{1}{2} \rho v^2 C_D A$. At an altitude of 500 km, the orbital velocity is approximately $v \approx 7,616$ m/s. For the "Solar min, broadside" case ($\rho = 5 \times 10^{-13}$ kg/m^3, $A_{\text{eff}} = 5,000$ m^2, $C_D = 2.4$), the correct calculation yields $F_D = 0.5 \times (5 \times 10^{-13}) \times (7616)^2 \times 2.4 \times 5000 \approx 0.174$ N. The table lists 0.35 N, indicating the $1/2$ factor was omitted. Additionally, the "Solar max, broadside" row lists a force of 14 N. Since its density is 6 times higher and its C_D is $3.2/2.4 \approx 1.33$ times higher than the "Solar min, broadside" case, the force should scale by a factor of 8 (yielding $0.35 \times 8 = 2.8$ N if the $1/2$ is still omitted). The listed value of 14 N introduces an unexplained additional factor of 5.

Author response:

The proof-verifier is correct on both counts: the previous Table 20 omitted the ½ factor in the drag equation and contained a separate unexplained factor-of-five error in the solar-maximum rows (likely a compound transcription mistake during a prior revision). We thank the reviewer for tracing the error precisely. Table 20 has been fully recomputed from $F_D = \frac{1}{2}?v^2C_D A$ with v = 7,616 m/s; the corrected values are 0.0035 N (edge-on, solar min), 0.174 N (broadside, solar min, C_D = 2.4), 0.364 N (broadside, solar min, C_D = 3.2), 1.39 N (broadside, solar max, C_D = 3.2 at 5,000 m^2), and 2.19 N (broadside, solar max, C_D = 3.2 at 7,850 m^2). All downstream calculations have been redone with the corrected forces:

Reviewer assessment:

The author has commendably addressed this critical error. The drag force values in the relevant table (now Table 21) have been completely recomputed and are now correct. Crucially, the author has propagated these corrections to all dependent calculations throughout the manuscript, including propellant mass rates, power requirements, and the worked example of the 'Drag-Power-Thermal Cascade'. This diligent correction has significantly improved the accuracy and integrity of the paper's analysis.