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Space Elevator Architecture's

Architecture Note #25

Space Elevator Architecture's Debris Mitigation Roles

TOPICS:

- *Debris alert → Warning needs*
- *Debris sizing → as a threat variant*
- *Space Elevator Tether Movement → passive defense*
- *The Sentry System → an Architecture adjunct*
- *System Recovery → Post debris-event actions*

Proposed

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Personal Prolog

This is an Architecture Note. It is the opinion of the Chief Architect. It represents an effort to document ongoing science and engineering discussions. It is one of many to be published over time. Most importantly, it is a sincere effort to be the diary, or the chronicle, of the multitude of our technical considerations as we progress; along the pathway developing the Space Elevator.

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Space Elevator Summary Statement of Performance Attributes for Debris Mitigation

It may be a myth, but old story goes that once upon a time (circa 1895) there were only two automobiles in the entire state of Ohio, and they ended up colliding with each other. So, urban myth or not; It probably is **NOT** a good idea to think that “collisions” will not affect your system. In our case, it is collisions with space debris and/or “rogue” satellites.

The Space Elevator Transportation System will soon be beginning its next development stage; engineering validation. In this stage, all needed capabilities are reviewed for engineering realism, development risk, performance projections, test data and operations simulations availability, and more. In most cases, the Space Elevator performance will be derived from subsystems to be designed, developed, and built within industry’s Space Elevator Transportation System development program(s). In other cases, the performance capability sought will be provided by others; an entity not part of the development program. One such case will be “at large” / or “on the market” capabilities to resolve the real and potential threat from space debris and “rogue” space craft.

ISEC believes that debris mitigation concepts will be built, operating, and thriving before the Space Elevator Transportation System reaches operational status. To that end, this paper serves as the initial characterization of how the Elevator can allocate the needed performance to a system then available. That system would serve as Sentry; capturing, destroying, and / or removing the debris threat. Additionally, other “topics” must be addressed.

Debris Alert

ISEC foresees a close and interactive communication with the military Combined Space Operations Control Center; known familiarly as CSpOC. CSpOC is responsible for tracking the thousands of debris pieces and providing the orbital parameters of those pieces to operating space users. In addition, commercial capabilities have emerged which offer forming and formatting that information; operationally satisfying their commercial customers. Analytical Graphics, Inc.'s ExoAnalytic Solutions has been active in this regard for years.

At any rate, the Space Elevator team expects that the Sentry system operator will be able to depend on a warning forecast at 72 hours (tbr), of a convergence / close approach to a Space Elevator tether location (accuracy tbr). This closure accuracy will improve (improvement tbr) as convergence approaches. The Space Elevator team expects the commercial team will hold a place on the Debris Mitigation Chair in the Space Elevator's Headquarter's Primary Operations Center (HQ/POC). The Space Elevator team expects to share the elevators self-surveillance data and other location information with Space Situational Awareness authorities (tbd).

Debris Size

The Space Elevator team foresees that the Space Elevator tether will be able to withstand "collisions" of space debris when the debris is small (size tbd). That engineering character (e. g. size, mass, and speed) has not yet been assessed AND the operational tether maintenance concept is still being defined. It is expected that the Space Elevator Tether Climber will be able to detect tether "scars", and the Climbers are expected to have some level of minor tether repair capability.

In any case, the team expects the Debris Mitigation Chair to work with its Space Situational Awareness member to predict damage of an impending collision, assess the damage caused by collisions not predicted or that could not be avoided. Damage assessment is an imperative; pre & post event.

Space Elevator Tether Movement

The Space Elevator team has long cited the capability of the tether to move away from an impending collision. It is much like a simple “jump rope” movement; the movement generated by movement of the Earth Port’s Tether Terminus with movement augmented by Reel In–Reel Out (RIRO) spools at the Earth Port and at the Apex. Simulation work is necessary but the impact of such a motion on tether / climber operations appears to be negligible. The team would rather have to “jump” rope only when necessary. In any event, the jump rope motion will be retained within our Debris Mitigation efforts.

The Sentry

The Space Elevator team has decided to examine an added capability within Debris Mitigation. In a concept called “Sentry”, space debris will be intercepted and removed before a collision takes place. Debris headed for a collision with a portion of the Space Elevator will have intercept priority but, if otherwise not encumbered by that priority; the Sentry will gather and dispose of other space debris as a matter of course.

The team proposes that the Sentry be independently built as its engineering competencies are developed. Its initial operations are dictated by **its** schedule; not the Space Elevator’s schedule. However, it should be operational as part of the Space Elevator Architecture as part of the Elevator’s Tether deployment and build up. In our terms, by Sequence #4 - (See Architecture Notes 6,7, and 8).

The team foresees a concept in which Sentry debris capture satellites would be in elliptical orbits within the tether’s lower region; at least including the “debris belt” (**tbr**). The number of debris collectors needed will be determined based on a flight operations analysis; with periodicity and revisit established by the 72 hour (**tbr**) warning window and the number of captures needed to maintain mitigation.

Space Elevator Recovery Operations

The ISEC team has done little in this regard; but in the coming months ISEC will begin definition of Tether & Climber operations fashioned to minimize the impact of a tether break. A key aspect of recovery operations will be where the break occurs. In many cases, the lower portion and attached objects will reenter; being destroyed. In other cases, the altitude of

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the break would lead to the tether moving away from reentry and thus be accessible by the RIRO's. Additional RIRO's would be valuable in that circumstance. The economic value of the payloads in the several climbers affected by a break also makes recovery operations mandatory. (Dah!)

In closing, Space Elevator Outreach Program

Space debris is expected to be part of space operations for an extended period in this century. The real mitigation approach is the establishment of policy and actions that will prevent, or at least extensively reduce, the creation of debris in the first place.

This paper is ISEC's attempt to document the approach to mitigate the Space Elevator mission impact and safety issues when space debris meets the Space Elevator's tether.

We strongly suggest that other activities confront the issue. In the era of space debris, we all live in Ohio.

More to be supplied --

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