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Version 1.3

Deliverable A

**Requirements and Interface Document**

System: MIT Space Elevator Team Beamed Ribbon Climber

Component or Subsystem: Microwave Beaming System

Team Name: The Naïve-About-Optics Team (NAOT)

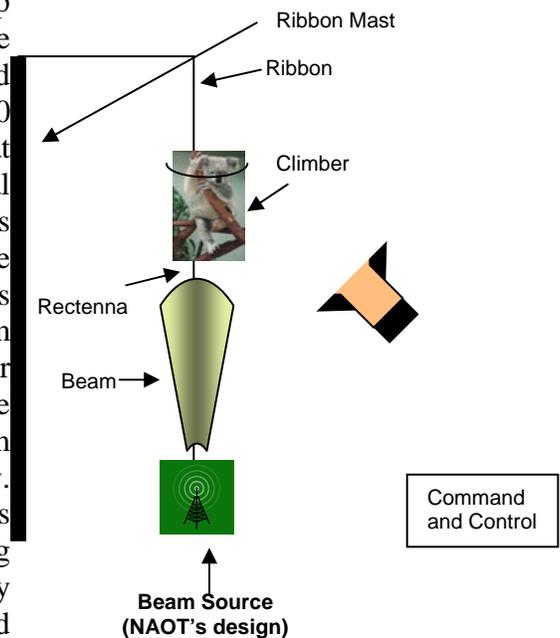
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**1. Component Description**

The NASA Centennial Challenges were created to help stimulate interest in the concept of a Space Elevator. The Power Beaming competition at these challenges required teams to design a robotic climber capable of ascending 100 meters of ribbon in 50 seconds. The rules dictate that power for the climber can only come through an external beam, and the use of sunlight is strictly prohibited. MIT's Space Elevator Team (MITSET) has chosen microwave radiations as the source of power for their climber. It is NAOT's goal to design the source of this microwave beam for MITSET's robotic climber. The ability of the climber to meet the required 2m/s average speed relies on the ability of the power source to provide a continuous beam of microwave radiation to the climber's rectenna array. This must be accomplished despite the rapid oscillations the climber is expected to experience and over varying distances. The rectennas also require a beam of circularly polarized microwave radiation, which must be created and directed toward them even though most common microwave generators (magnetrons) create linearly polarized non-collimated radiation.



## **2. Functional Requirements**

Our team's subsystem will necessarily be complex, so to set ourselves an achievable goal, we have separated requirements into first-level and second-level requirements, the latter being those that MITSET would benefit from, but aren't crucial to the system's performance.

### 2.1 First-Level Requirements

- 2.1.1 The system must transfer at least 400W of true power over a period of 50 seconds to a 1.8m diameter horizontal rectenna oscillating with an amplitude of 1m situated at a varying altitude of 10 to 60m.
- 2.1.2 If any components are added to the climber, their total weight cannot exceed 8.5kg
- 2.1.3 If any components are added to the climber, they must comply with all climber requirements as detailed in section 2.2.1 of the NASA Space Elevator Centennial Challenge rulebook[\[1\]](#).

### 2.2 Second-Level Requirements

- 2.2.1 The beam source must be able to be turned on.
- 2.2.2 The beam source must be able to switch off in 5 seconds of a stop command.

## **3. Constraints**

- 3.1 The transferred power must be microwave radiation circularly polarized at 5.81GHz
- 3.2 The system must comply with any applicable regulations as well as, so far as possible, the laws of physics.

## **4. Interface Definition**

Just as with the requirements, this section has been divided into primary and secondary interface definitions. Secondary interface definitions are not crucial to the system's integrability with the rest of MITSET's hardware, but would benefit them if included.

### 4.1 Primary Interface Definitions

- 4.1.1 The power source must have its own generator or comply with a 100kVA apparent power, 120V (single phase), 208V or 480V (three phase) generator using a bare wire connector.
- 4.1.2 The beam source must fit around a ribbon anchor connected to the ribbon, modeled as an immobile .5m-side cube sitting on the ground, or must provide power away from it.

- 4.1.3 The beam must be safe for spectators situated at a distance of 50m from the climber ribbon anchor as well as for any operators situated closer than 50m from the ribbon anchor, or be operable from a 50m distance.
- 4.1.4 The beam source must be storable in a cubic box of 1.5m side.
- 4.1.5 The beam source must be assembled and connected from its stored state within 20 minutes with a team of 2 or 15 minutes with a team of 3.

## 4.2 Secondary Interface Definitions

- 4.2.1 The beam must have a master off switch.
- 4.2.2 The beam control box must have two 5V command output lines: “start” and “enable”.
- 4.2.3 The beam control connector should be a standard mini connector, McMaster 69355K74 or compatible. This connector will be on our control box. The beam source can use on-line connector such as McMaster 69355K71 or compatible, with enough cable to reach our control box.
- 4.2.4 The beam source must be able to stand on a semi-paved or compacted ground surface and must be able to level.
- 4.2.5 If the beam is not visible, the beam source must have a visible “beam is on” indicator light on it, and a 5V output line indicating the state of the beam. If there are multiple physical beam sources, the “beam on” line should be high if any of them is on, the “beam on” indicator light should be on each source, and the “master off” switch should kill all sources. The time delay between the command and the change in beam state must not exceed 1 second.
- 4.2.6 The beamed electromagnetic radiation must preserve the integrity of a 110m long 100mm wide vertical ribbon made of Siegler-USA GG-25A-20 material under a tension of 6500N.
- 4.2.7 The beamed electromagnetic radiation must preserve the integrity of a 110m long belay line of yet undefined characteristics situated 30 to 50 cm away from the ribbon.

## 5. **Verification**

The team will be required to prove that they fulfill any secondary interface definitions, or second-level requirements. The following tests will be performed to verify that the system satisfies the rest of this document:

- 2.1.1 The design will be tested using sensitive measuring equipment to test the power output from a rectenna placed in the microwave beam produced by the system. It will be measured at varying distances up to 60m. This will take place on the track possibly with some shielding for the microwaves placed behind the test.
- 2.1.2 Will be tested by weighing the finished system on an accurate scale.
- 2.1.3 Will be met by making sure everything meets the specifications set forth in the NASA Space Elevator Centennial Challenge rulebook.
- 3.1 The Microwave radiation transmitted will be applied to a rectenna to measure the output voltage.
- 3.2 MIT’s safety office will be asked to verify that the system abides by all known applicable regulations.

- 4.1.1 Power input into the system will be carefully measured during the extent of the field test.
- 4.1.2 Will be tested by building a .5m box and placing the beam source on/around it.
- 4.1.3 Shielding may be used to ensure safety of spectators and the MIT safety office will help to ensure that the system is safe.
- 4.1.4 The beam source will be disassembled and placed in a 1.5m box to demonstrate that it is storable.
- 4.1.5 Two or three team members, as appropriate, will be timed as they assemble the beam source.

Signatures

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<sup>[1]</sup> [http://www.elevator2010.org/site/documents/climber\\_rulebook\\_2007.1.00.pdf](http://www.elevator2010.org/site/documents/climber_rulebook_2007.1.00.pdf)