408W- Icarus
Team ICARUS

I.C.A.R.U.S. – Instantaneous Coordinate Acquisition and Routing Utility Satellite

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Problem Statement

The Global Positioning System (GPS) is a satellite constellation designed to provide instantaneous and precise location information for private/public, commercial, and military users. As current satellites ages and new technology improves, a new generation of GPS satellites must be deployed to ensure the United States has a strategic advantage and better positioning, navigation, and timing. This is *especially* true in a period of heightened tensions with nations of comparable technologies and denied signals.

Design Calculations and Analysis

The GPS protocol operates on Three wave bands, L1 (1.5-1.6 Ghz), L2 (1.2-1.3 Ghz), and L5 bands (1.1-1.2 Ghz); the satellite requires 3 Traveling Wave Tubes(TWT) for each. The common Parameters for the TWTs were:

- Power: 1000 Watt output, ~5882.4 Watts Total, 3529.44 Watts with Depressed Collectors
- Gain: 45 dB
- Beam Power: 1000 Volts, 5.8824 Amps
- Efficiency: 17%
- Helix Radius = 12.901 mm
- Helix Pitch = 5.0712 mm

$\frac{r_b}{a} = \frac{3}{4}$

Number of turns: $\frac{L}{p} = \frac{16.29}{.2863}$

$Z_c \approx \frac{\beta_o}{2k}[RF(\beta_o a)]$ $\omega_p = \sqrt{\frac{je}{u_o \varepsilon_o m}}$

The needed current is $I_o = \frac{P_o}{\eta V_o}$

Helix pitch: $p = 2\pi \frac{\omega}{\beta_o} \frac{a}{c}$

The helix radius is: $a = \frac{4r_b}{3}$

L1 TWT:
Zc = 0.006196 Ohms
Length = 73.0148 cm
Number of Turns = 143.9786

L2 TWT:
Zc = 0.12511 Ohms
Length = 34.4102 cm
Number of Turns = 67.8538

L5 TWT:
Zc = 0.19464 Ohms
Length = 30.9878 cm
Number of Turns = 61.1051

The satellite employs three cesium atomic clocks each with parameters:

- Power: 35-50 W
- Lifetime: 7-15 years
- Precision 10^-16 seconds
- Element: Cesium 133

The wavenumber is $\beta_o = \frac{\omega}{u_o}$

The beam velocity is: $u_o = \sqrt{\frac{2eV_o}{m}}$

$I_o = \pi r_b^2 (2\ A/cm^2)$

$k = \frac{\omega}{c}$

Power System:

- 40m^2 Gallium Arsenide (GaAs) Junction Solar Cells
  - 22,200 Watts
  - 18 kWh in 6 hours
  - Efficiency: 35%
- 20,000 Lithium Ion cells
  - 900 kg
  - Thermal load: -20°C to 60°C (-4°F to 140°F) for discharging and 0°C to 45°C (32°F to 113°F) for charging

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w_c = 5 * w_p;
Magnetic field --> wc = e*B / m_e
B_tesla = (w_c * m) / e;
B_gauss = 10000 * B_tesla;
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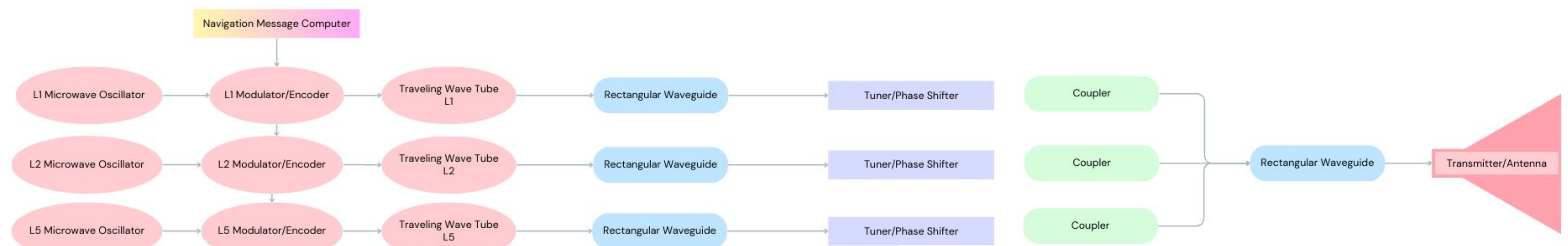
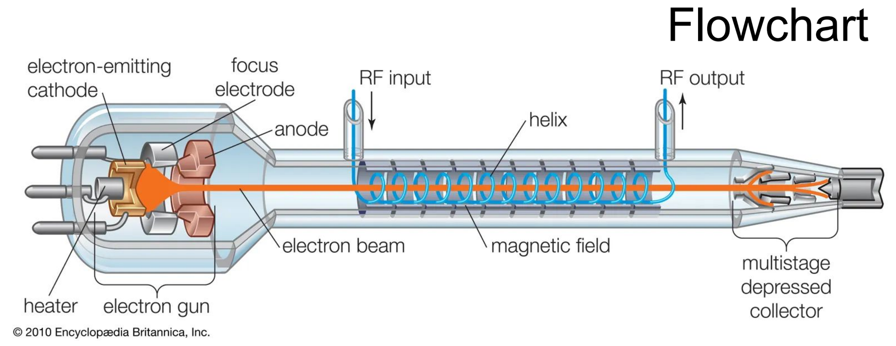
Final Design

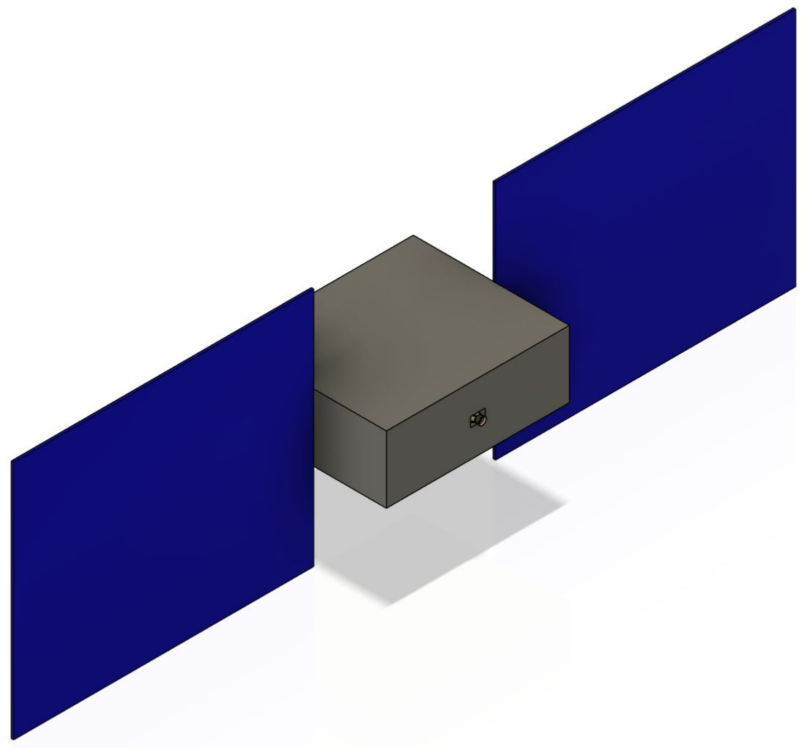


Flowchart



TWT Diagram

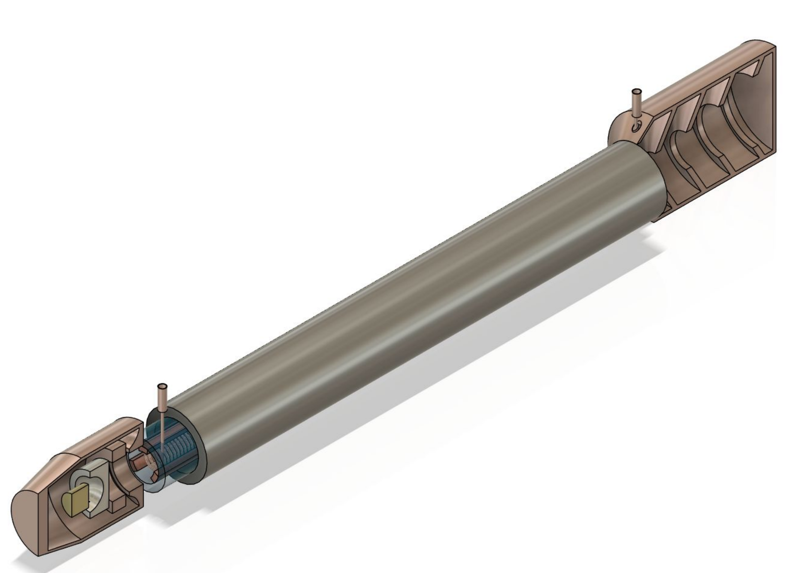
The final design consists of three parallel chains of microwave sources, phase shifters, and waveguides. These signals are then combined with 3dB couplers, and finally passed to the rectangular waveguide and Horn Transmitter to be broadcasted to earth. Certain details are undeterminable/classified due to the proprietary national defense nature of the project.



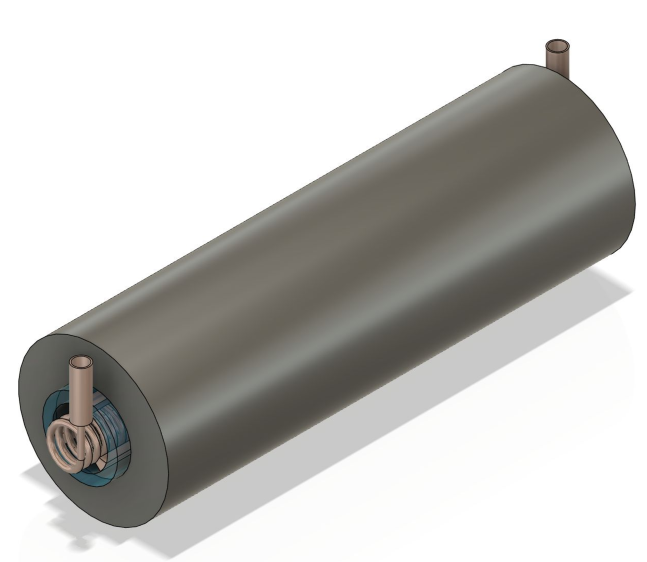
Cesium 133 Atomic Clock

The Conical Horn antenna will allow a beam width of 120 degrees, enough to cover an entire hemisphere of the earth. Dimensions: Aperture Diameter ~ 0.200m, Slant Height ~ 0.299m, Axial Length ~ 0.288m, Flare Angle ~ 30 degrees, Throat Diameter ~ 0.040m

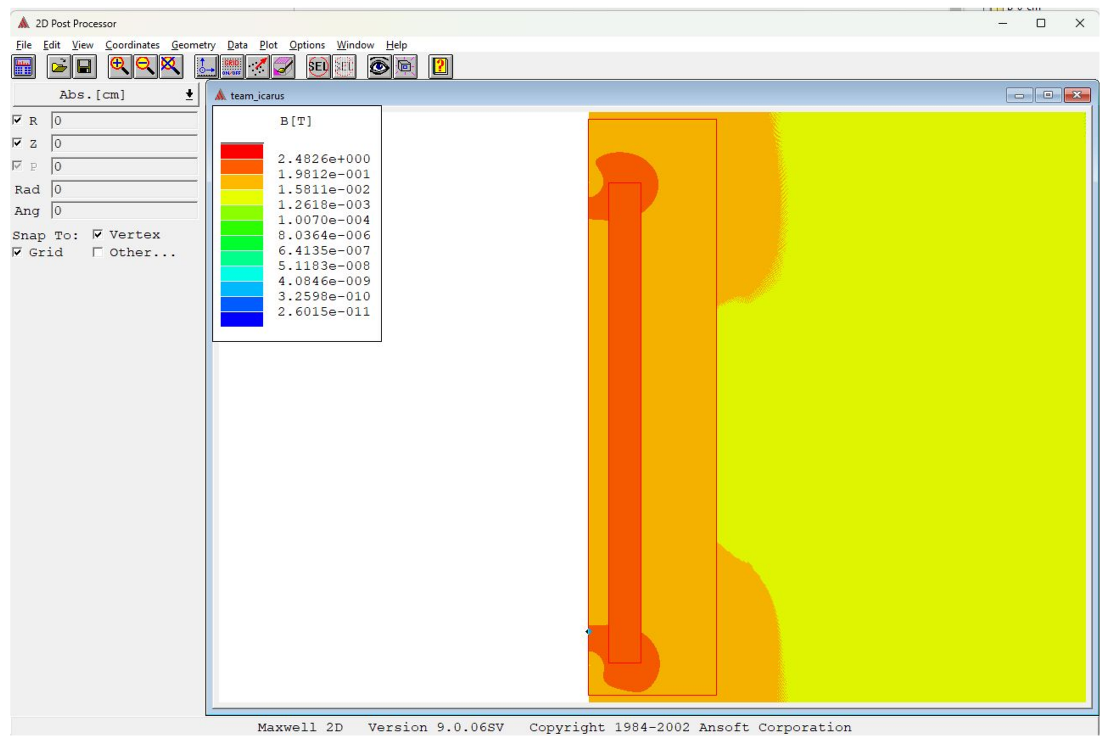
Prototype and Test Results



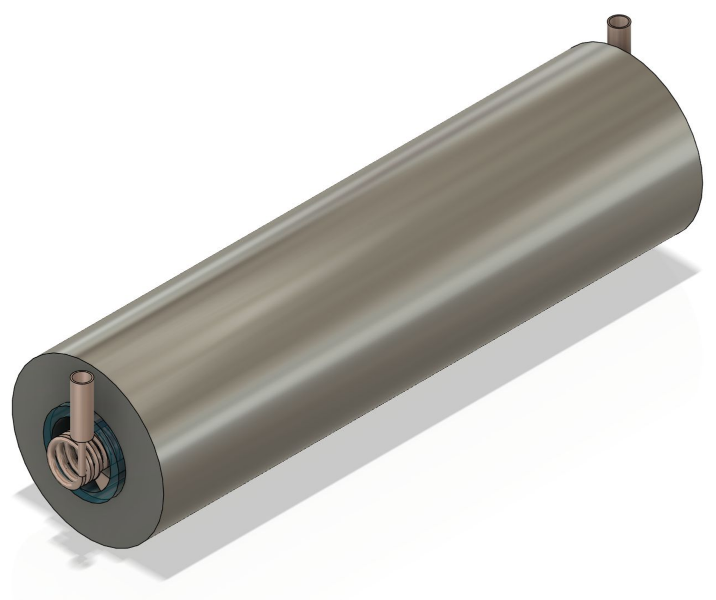
L1 TWT



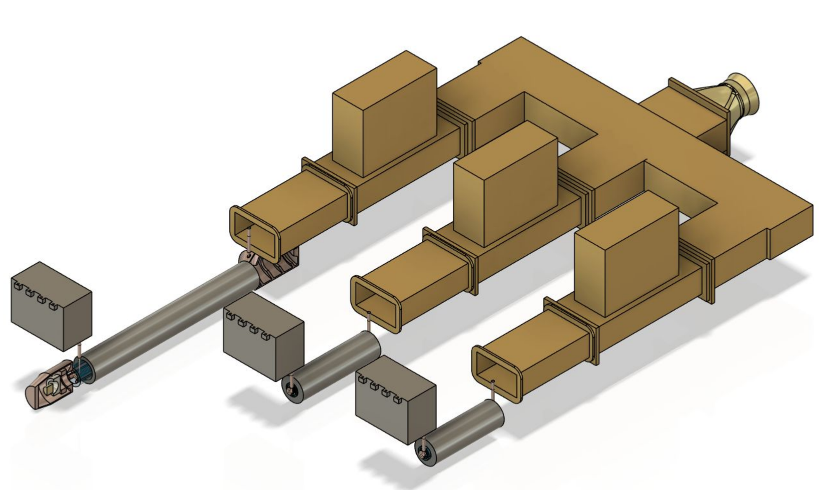
L5 TWT



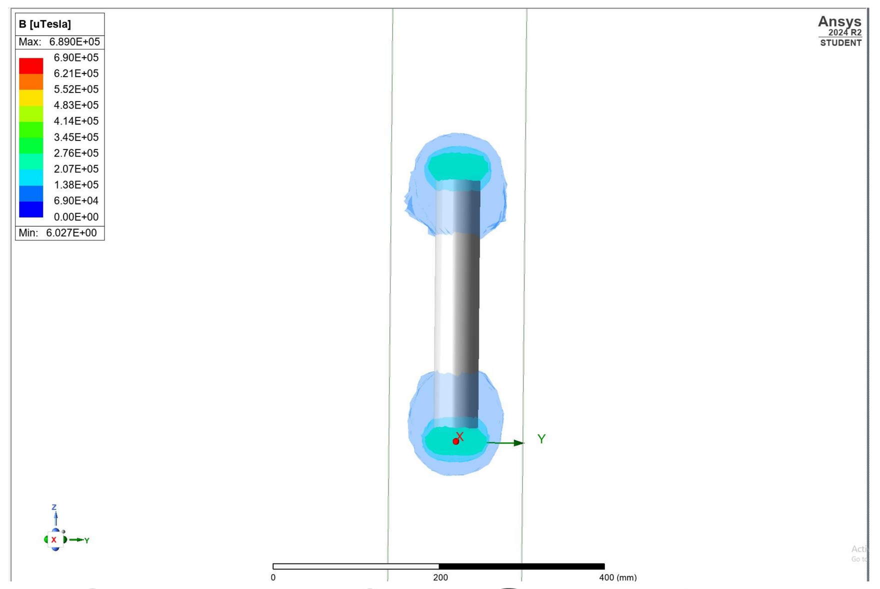
L2 TWT 2D Simulation



L2 TWT



Internal Microwave Assembly



L2 TWT 3D Simulation

Critical Design Parameters:
Orbital Mechanics:

- Orbital Period: 11.97 Hours
- Intended Constellation Addition: 12 satellites
- Orbital Distance: 12,540 miles (Medium Earth Orbit)
- 6 Planes
- 8724.05

Other Parameters:

- Lifespan: 15 years
- Accuracy: 30–500 cm

Oscillator