The Precision Expandable Radar Calibration Sphere (PERCS)

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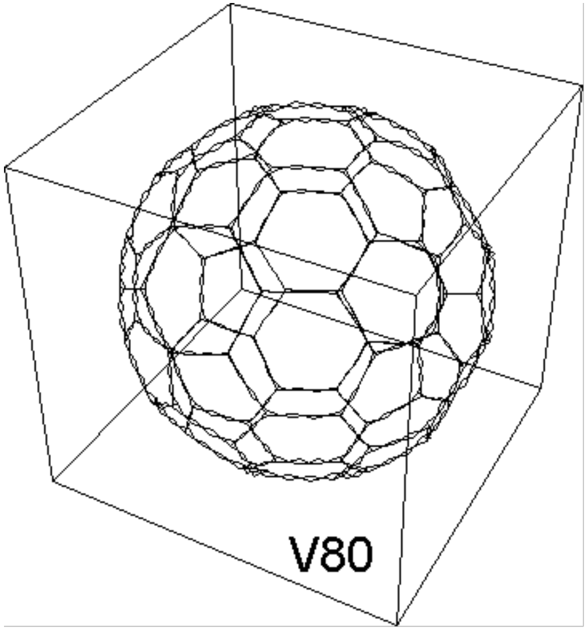
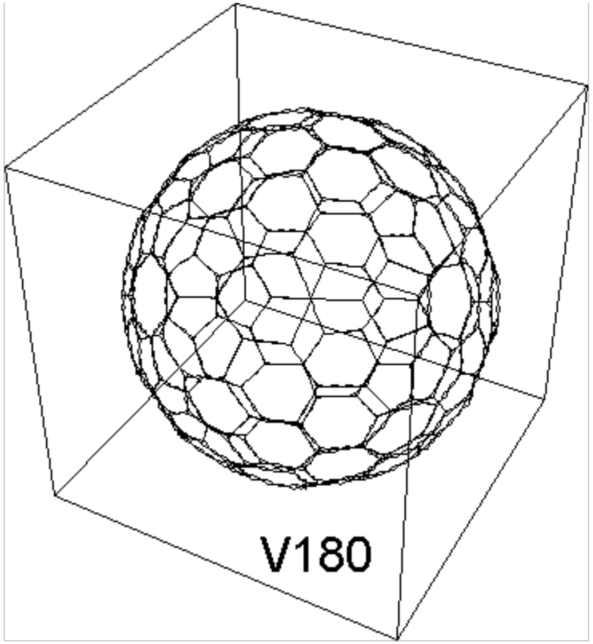
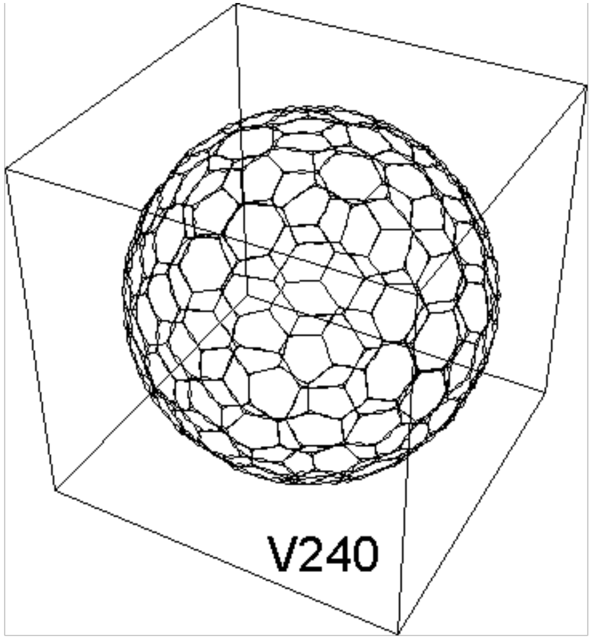
PERCS Objectives

- Provide *HF Radar Calibration* *Target* Using Spherical Wire Frame
  - Purpose: Calibration of Antenna Patterns for Space Weather Radars
  - Construct Model for RCS Testing
  - Construct Spaceflight Version
  - Launch into Low Earth Orbit
- Provide Optical Calibrator for *Laser Satellite Tracking*
  - Purpose: Calibrate Laser Tracking and Imaging Systems
  - Add Corner Cube Reflectors to Each Vertex of Wire Frame
  - Obtain Precise Measurements of Sphere Position and Orientation
  - Measure Electro-Dynamic Drag on Satellites in Low-Earth Obit
- Study Deployment, Characteristics, and Plasma Interactions of *Large Polyhedral Structures in Orbit*
  - Purpose: Determine Limits on Construction and Lifetime of Large Wire Frames in Space
  - Demonstrate Automated Deployment in Space
  - Study Electro-Dynamic Drag by Magnetic Field Interactions with Large Wire Frame in Space
  - Study Electric Field Excitation by High Power Electromagnetic Waves

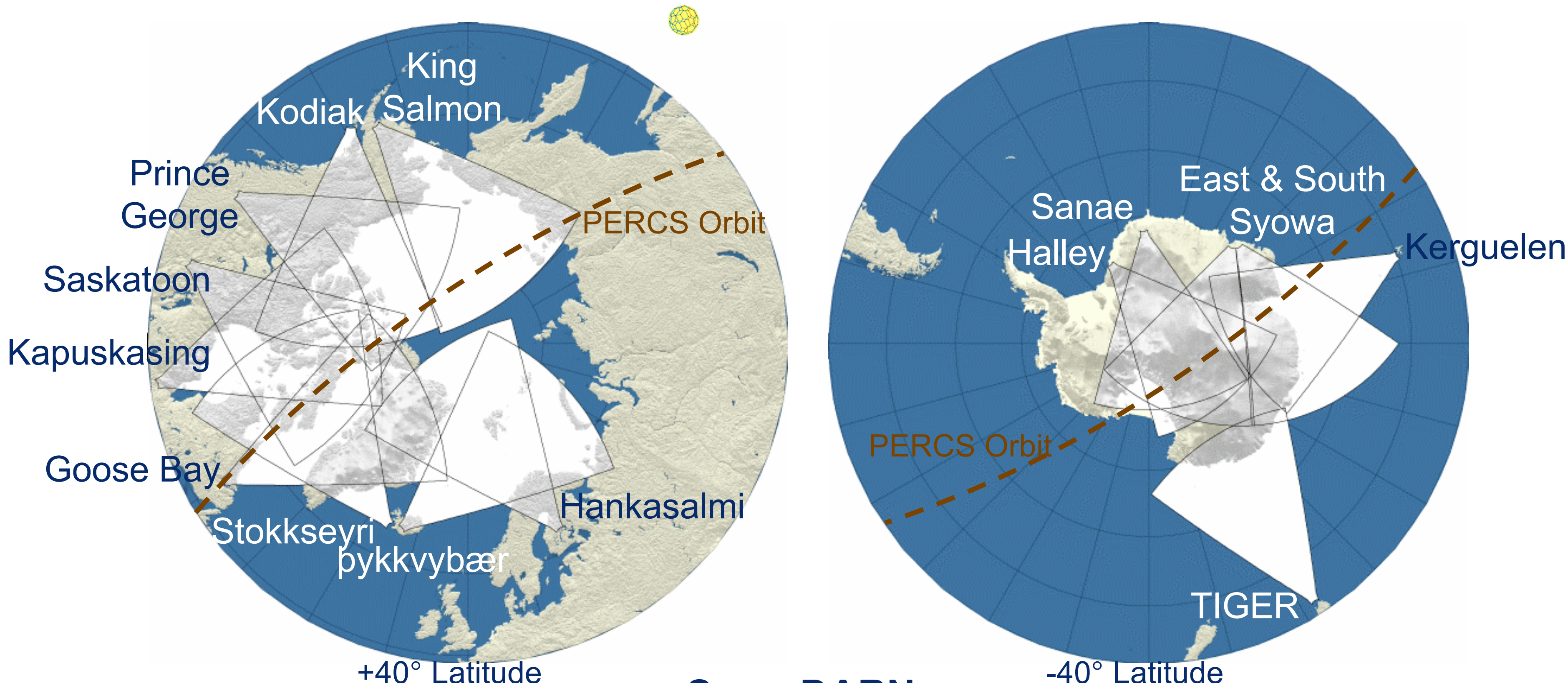
V80, V180, V240 Deployed Spheres







PERCS at 80° Inclination Calibrates the Worldwide SuperDARN Radars

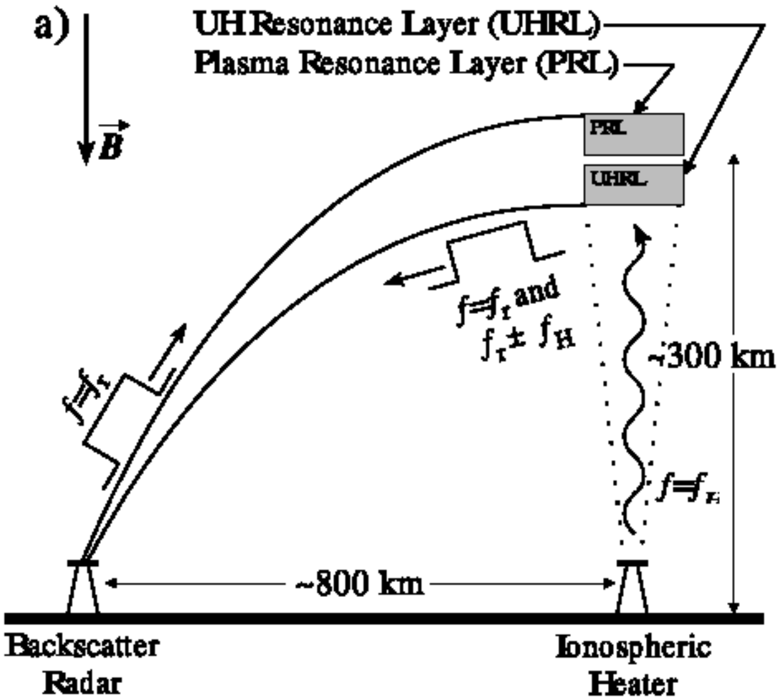


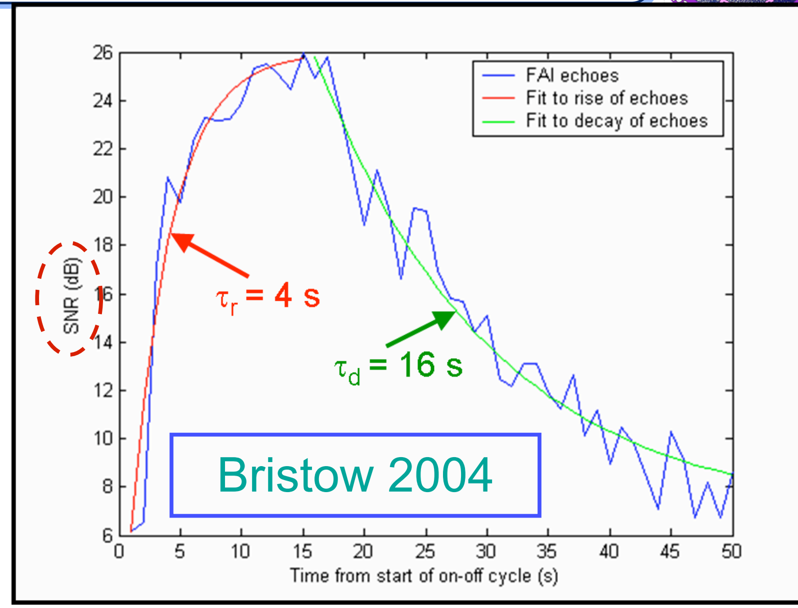
SuperDARN

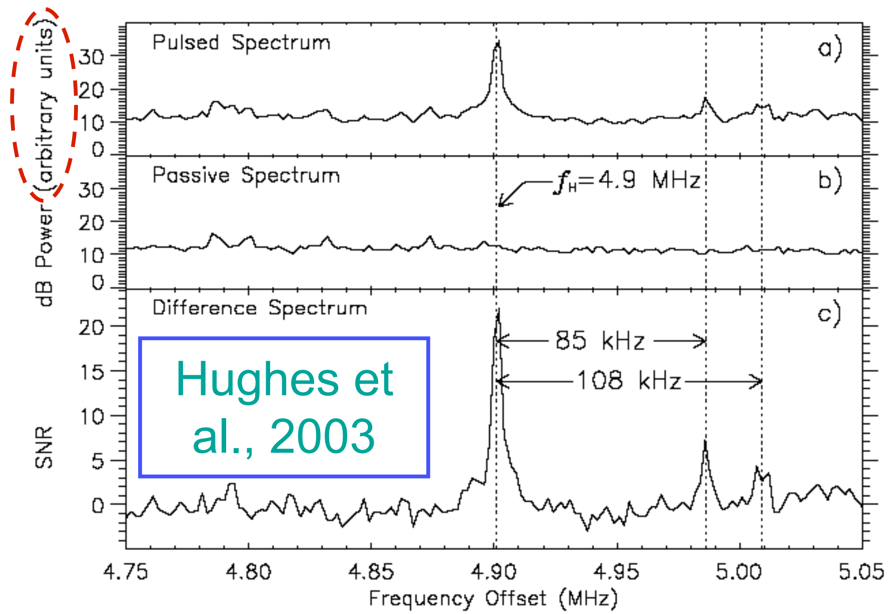
An International Radar Network for Studying the
Earth's Upper Atmosphere, Ionosphere, and Connection into Space

PERCS Operational Utility: (1) Absolute System Calibration from 8 to 20 MHz
(2) Characterize Effects of Ionospheric Refraction

Unknown Echo Strengths for SuperDARN Backscatter from Meteors Trails and Ionospheric Irregularities

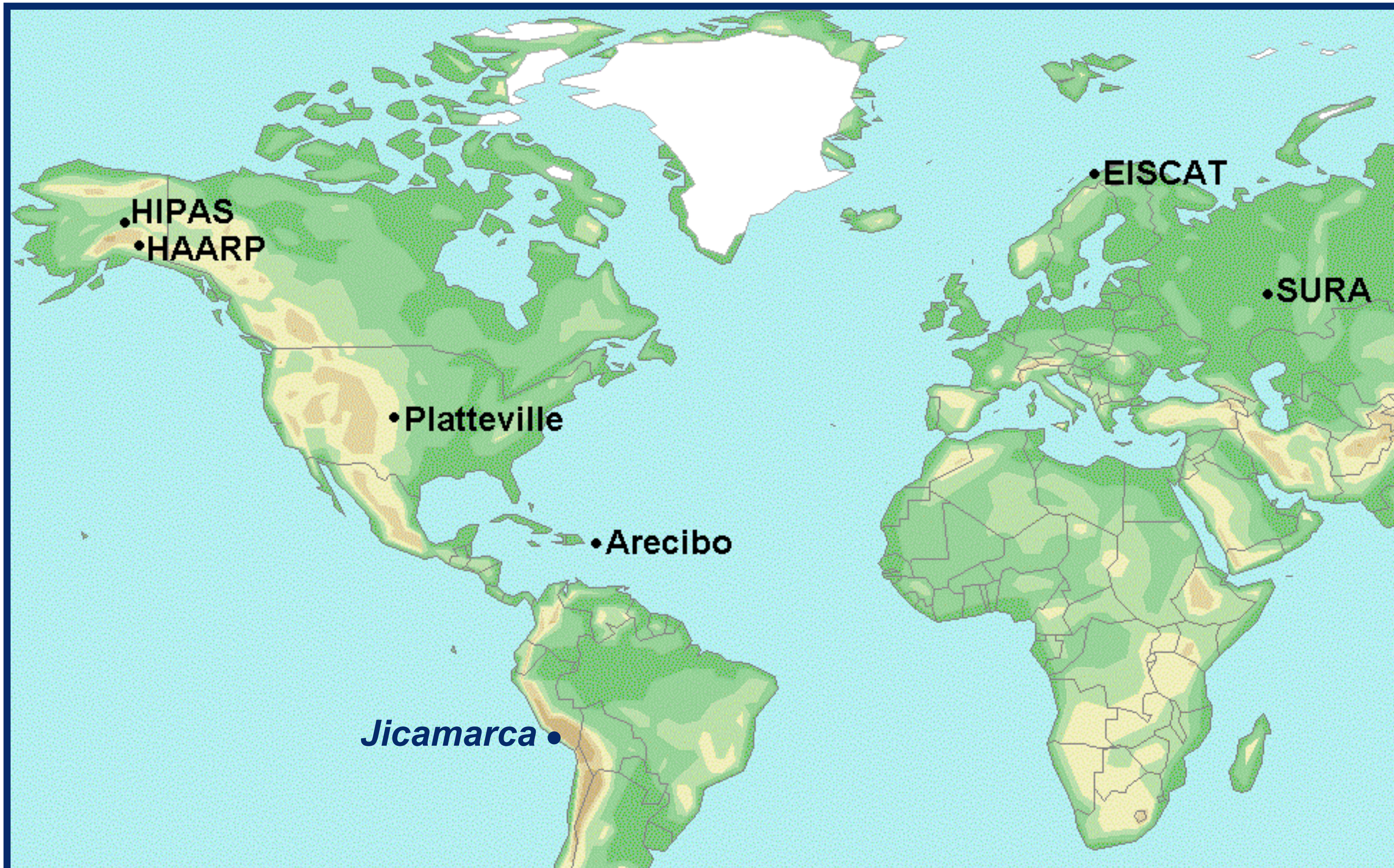






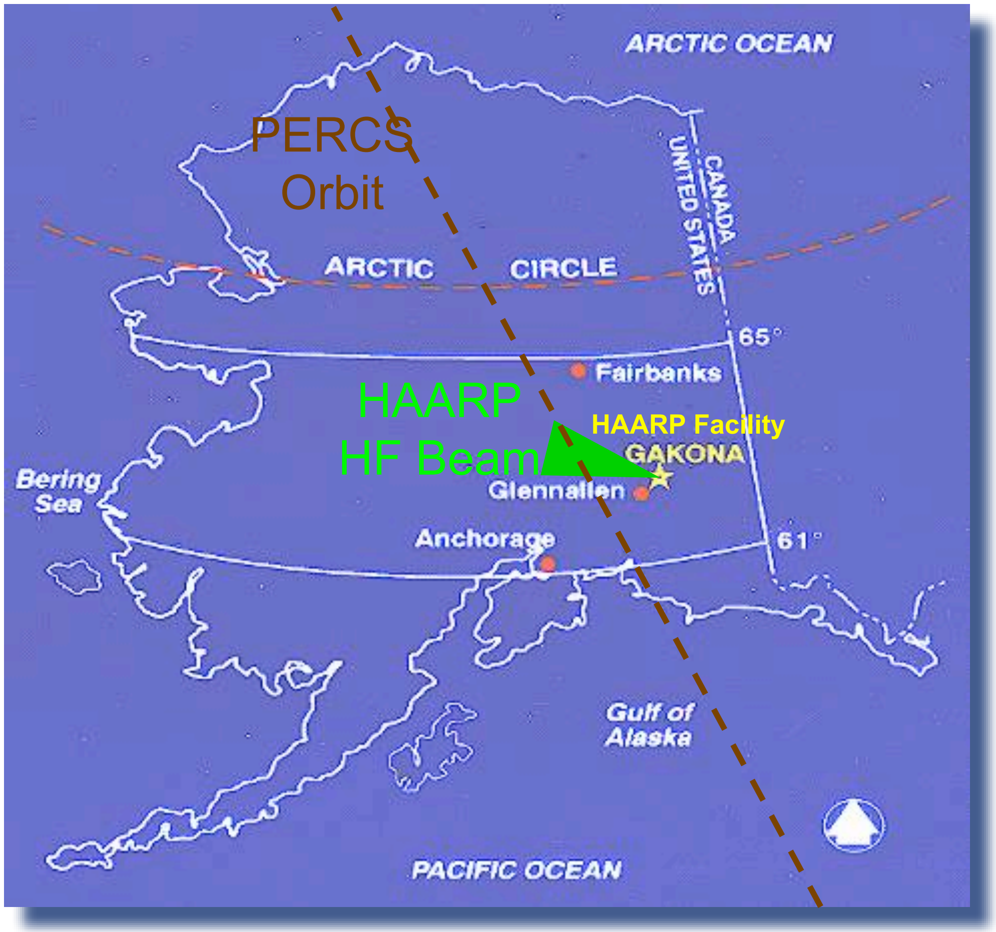
- PERCS Calibration of SuperDARN Radar
  - Absolute Return Power Determination
  - Relate Measurements from one Experiment to the Next

Past, Current and Future HF Ionospheric Modification Facilities



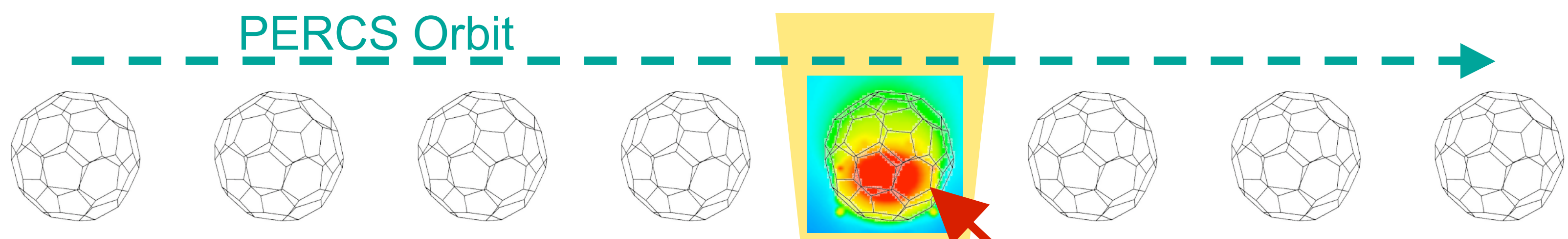
Arecibo Conjugate

HAARP Instrument Experiments with the PERCS

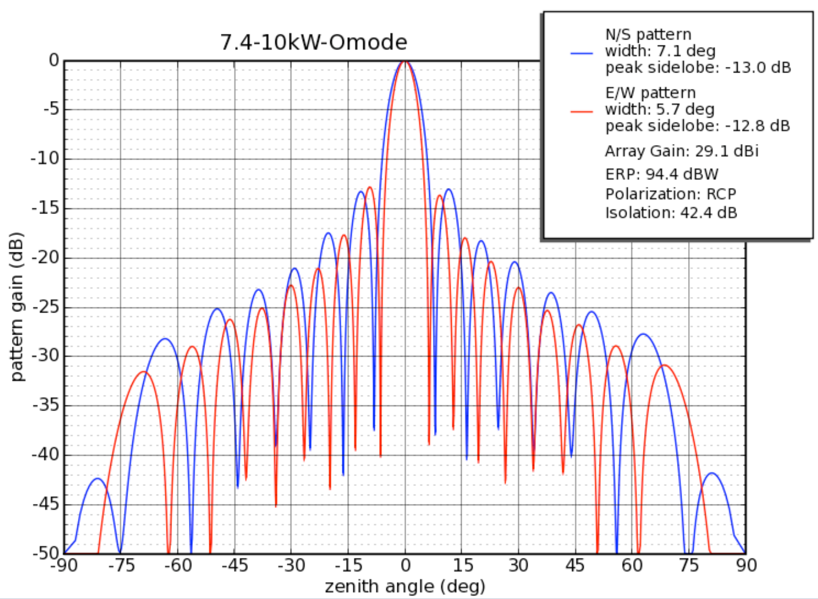


- **PERCS Application to High Power HF Facilities**
  - **Absolute Calibration of HAARP Antenna Pattern from 2.8 to 10 MHz**
  - **Precise Measurements of Performance for HF Radars that Support HAARP**

PERCS Applications for HAARP



- **HF Antenna Calibration**
  - **Absolute System Sensitivity**
  - **Faraday Rotation Scatter Target**



PERCS EM Characteristics

- **Conducting Edges**
- **Resonant Structure**
- **Large Internal Electric Fields at High Frequencies**
- **EM Effects on Orbit**

Radar Constant

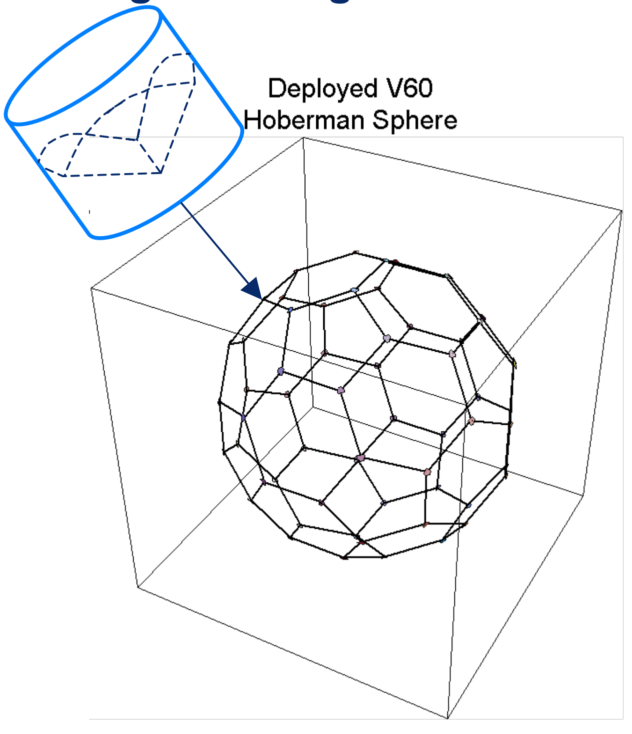
$$\frac{(4\pi)^2}{P_t}\,\frac{4\pi}{\lambda_0^2}\,\frac{L(\theta)^2}{G(\theta)^2} = \frac{\sigma_0}{P_{r0}(\theta)\,R_0^4} \equiv C_0(\theta)$$

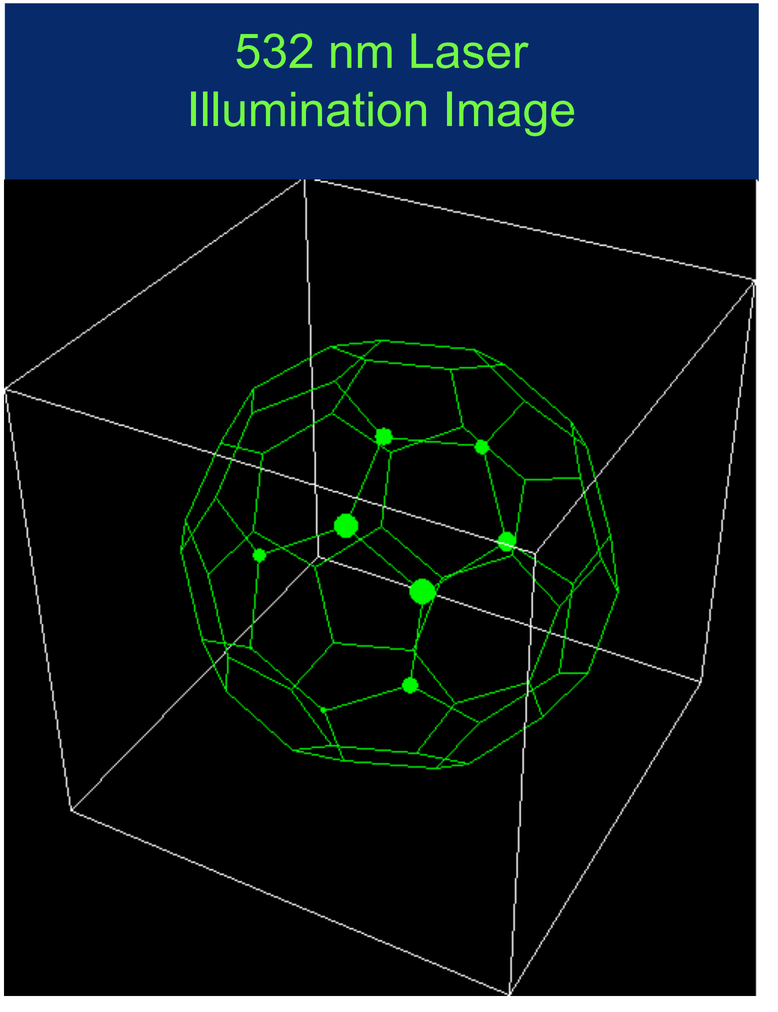
$$\sigma(R,\theta) = C_0(\theta)\,P_r(R,\theta)\,R^4$$

HAARP Array

Objective 2: Space-Based Laser Calibrator for Laser Ranging and Imaging Telescopes

- One Corner Cube Reflector at Each External Vertex Hinge
  - Small Diameter to Match Hinge Size and Compensate for Velocity Aeration
  - Provides Precise PERCS Position using Laser Ranging and Tracking
  - Flight Heritage from ANDE-RR

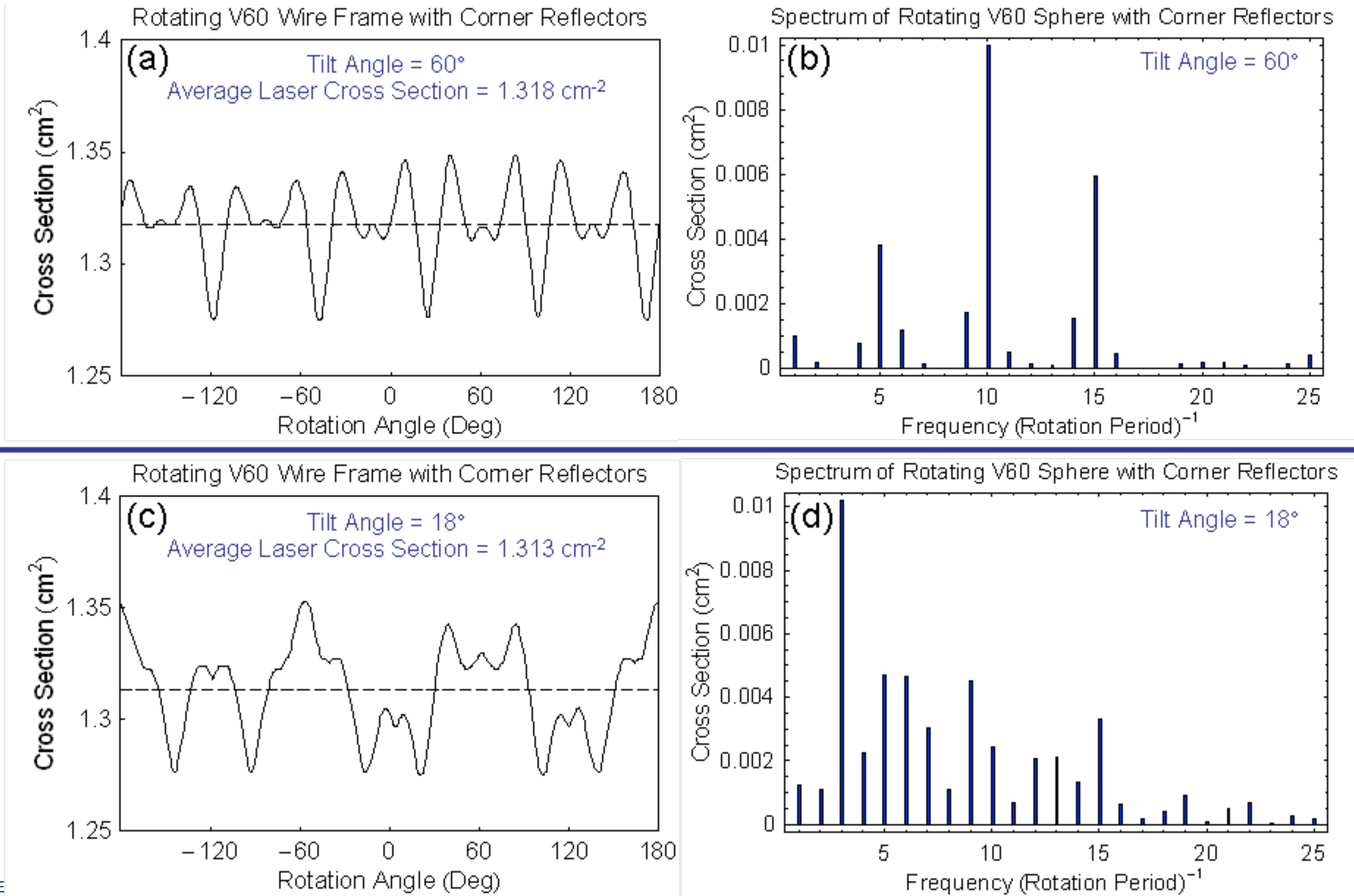




View PERCS with Laser Ranging Telescopes

- Laser Tracking of the PERCS Sphere
  - Retro Reflectors at 180 Vertices
    - 3 Reflectors Per Vertex on the Outside of PERCS
    - 3 Reflectors Per Vertex on the Inside of PERCS
  - 1.2 m Spacing of Retro Reflector Vertices
  - 1080 RR's Distributed Over 10 Meter Diameter Sphere
  - Unique Reflection Pattern to Determine Sphere Orientation
  - Large Number to Provide Strong Return of Laser Signal
- Specifications: Fused Silica Corner Cubes
  - Size: 1 cm Diameter
  - RR Diameter is Small to Compensate for Velocity Aberration
  - Corner Cube Axis Tilted ~20 Degrees from PERCS Radius Vector
    - Stronger Reflection from Wide View Edges
    - Triplets at Each Vertex to Increase Optical Cross Section

Simulated Cross Section of Rotating V60 Polyhedron with Corner Cube Reflectors



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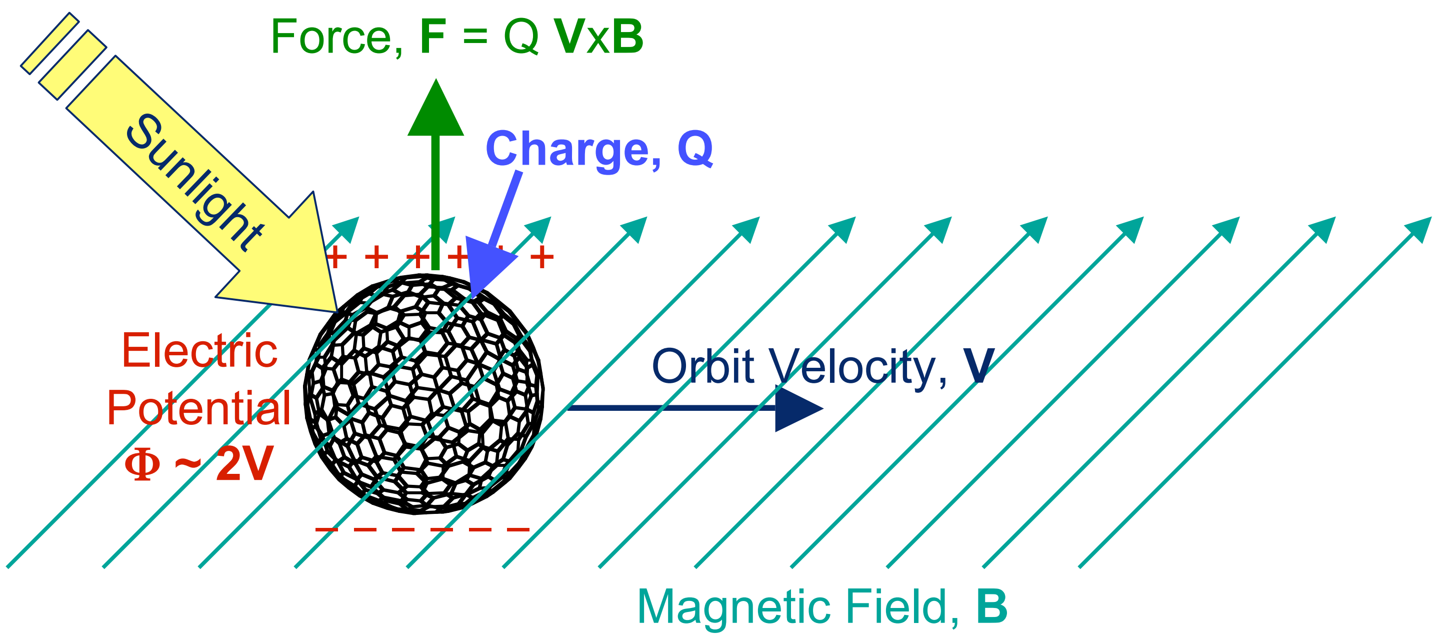
Objective 3: Electrodynamics and Deployment of Orbiting Wire Frame

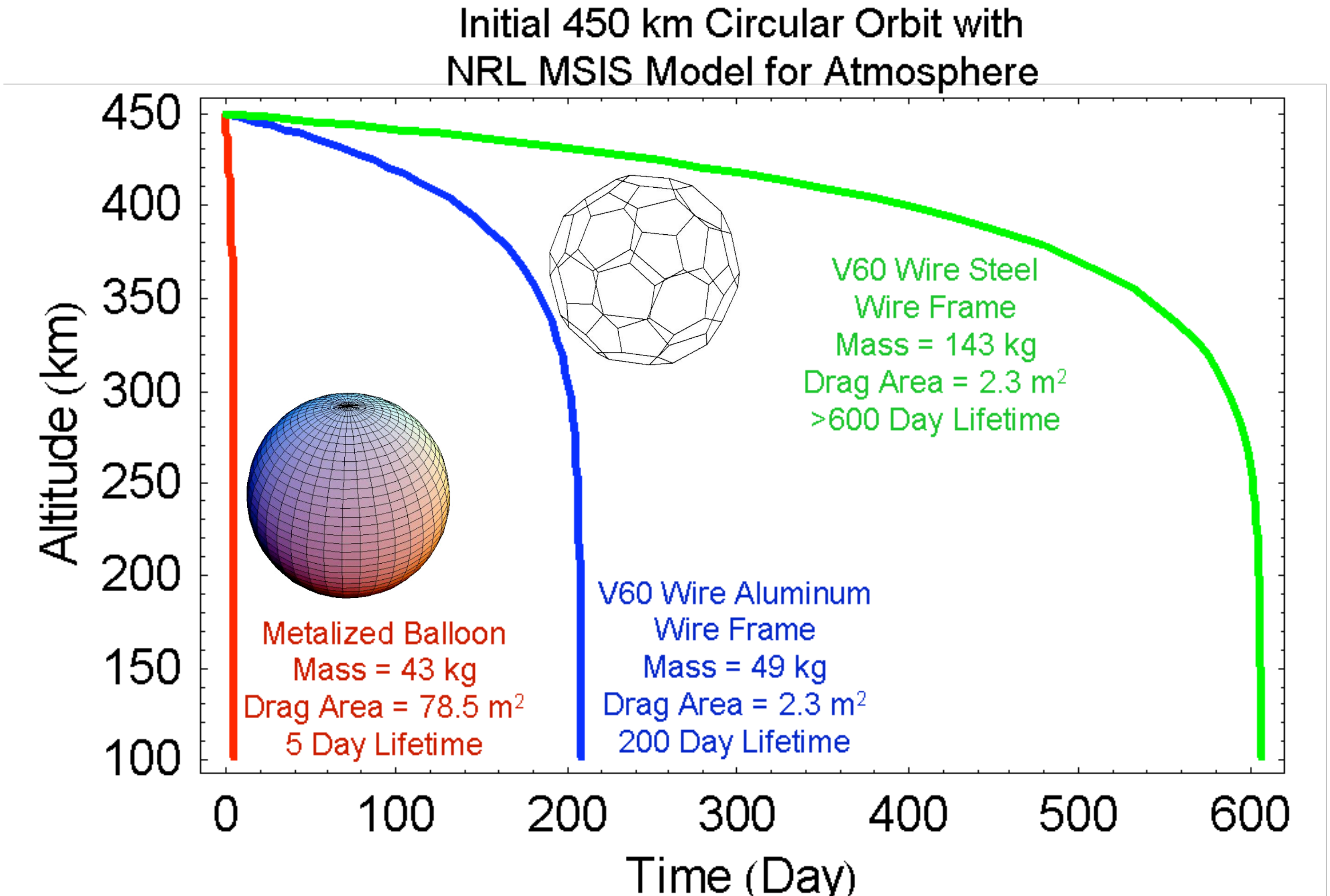


High Accuracy Precision Orbit Determination Required to Measure Perturbation Forces on PERCS

Packaging of PERCS for Launch

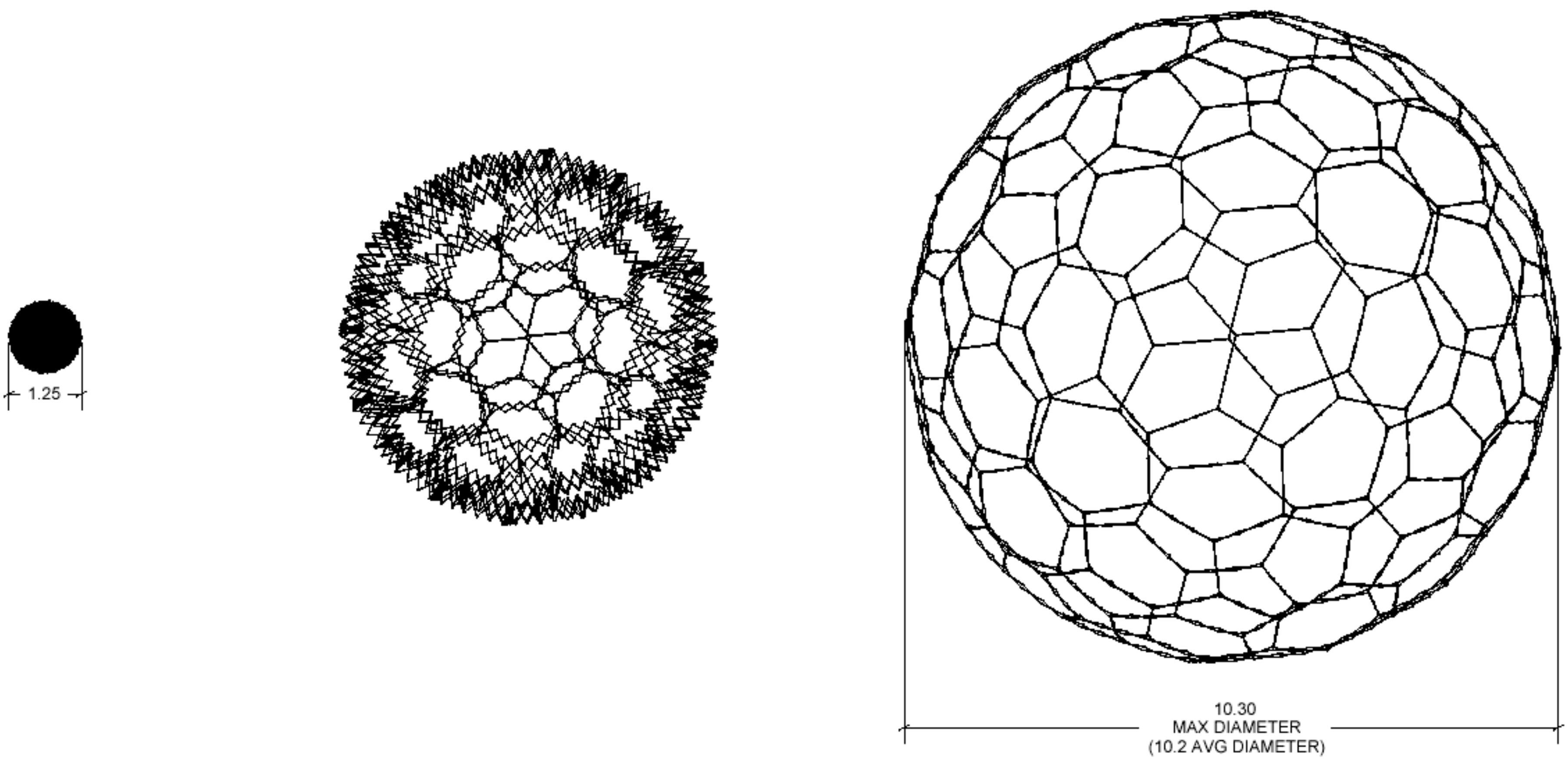
Radius = 1.009

Drag Limitations on Lifetime of 10 meter Spherical Radar Target

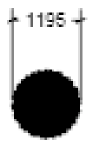


At the Orbit Altitude Between 600 and 800 km PERCS Will Last for More Than 6 Years

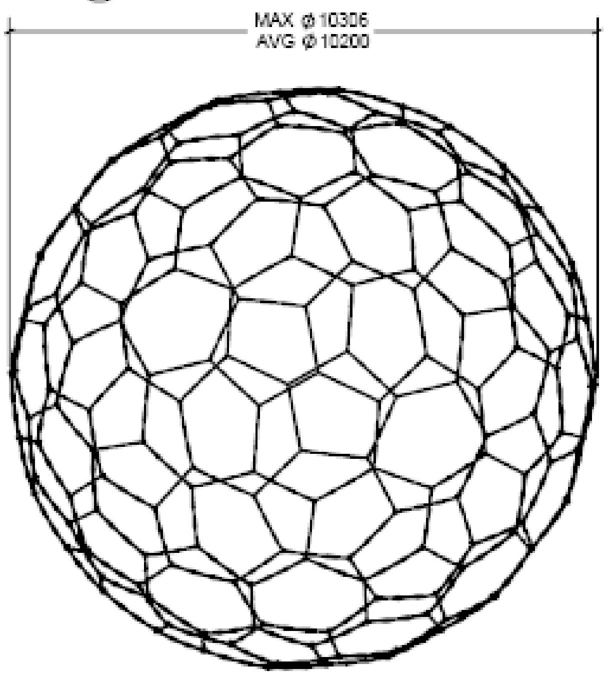
PERCS V180 with 1000-Fold Increase in Volume



PERCS Current Design (142 kg)



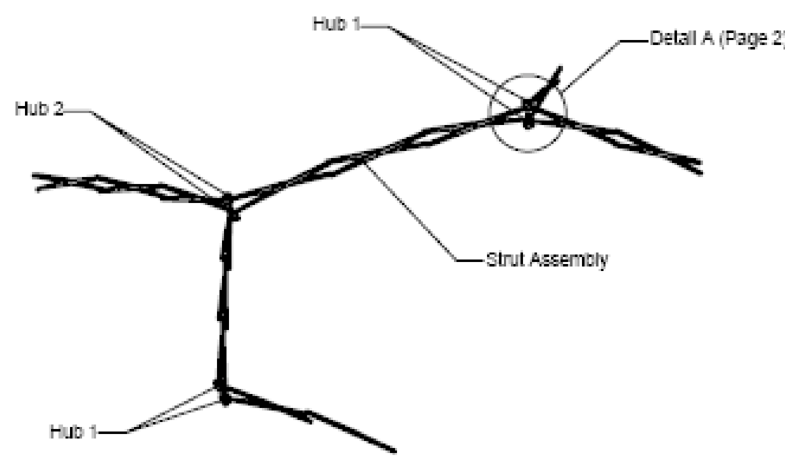
(01) NRL PERCS Retracted
1:75



(02) NRL PERCS Extended
1:75

Component	Material	Mass (kg)	Quantity	Component Mass (kg)	Component Weight (N)
Outer Hub Strut	6061-T6	0.063255	540	34.1577	335.087037
Inner Hub Strut	6061-T6	0.065186	540	35.20044	345.3163164
Center Strut (Pin)	6061-T6	0.064034	270	17.28918	169.6068558
Center Strut (Bearing)	6061-T6	0.063559	270	17.16093	168.3487233
6mm Flanged Bearing	Iglide T500	0.000178	2700	0.4806	4.714686
5mm Flanged Bearing	Iglide T500	0.000175	1080	0.189	1.85409
Standoff	Stainless Steel	0.001206	1890	2.27934	22.3603254
6mm Strut Pin	Stainless Steel	0.006207	1350	8.37945	82.2024045
5mm Strut Pin	Stainless Steel	0.004391	540	2.37114	23.2608834
Torsion Spring	Steel	0.0036	270	0.972	9.53532
Hub 1	6061-T6	0.01923	240	4.6152	45.275112
Hub 2	6061-T6	0.01922	120	2.3064	22.625784
Hub Pin	Stainless Steel	0.00215	1080	2.322	22.77882
Machine Screw	Stainless Steel	0.000279	1080	0.30132	2.9559492
4mm Flanged Bearing	Iglide T500	0.000094	2160	0.20304	1.9918224
Expansion Stop (Cup)	6061-T6	0.014521	180	2.61378	25.6411818
Expansion Stop (Cone)	6061-T6	0.004452	180	0.80136	7.8613416
Reflector Casing	6061-T6	0.018957	360	6.82452	66.9485412
Reflector	Glass	0.0019	1080	2.052	20.13012
Reflector Cup	Nylon	0.0006	1080	0.648	6.35688
Reflector Spring	Steel	0.0003	1080	0.324	3.17844
Reflector Washer	Steel	0.0001	1080	0.108	1.05948
Reflector Retaining Ring	Steel	0.0004	1080	0.432	4.23792
			Total Mass (kg)	142.03	
			Total Weight (N)	1393.33	

(03) Component Mass Table



(04) 1/60 Sphere Section
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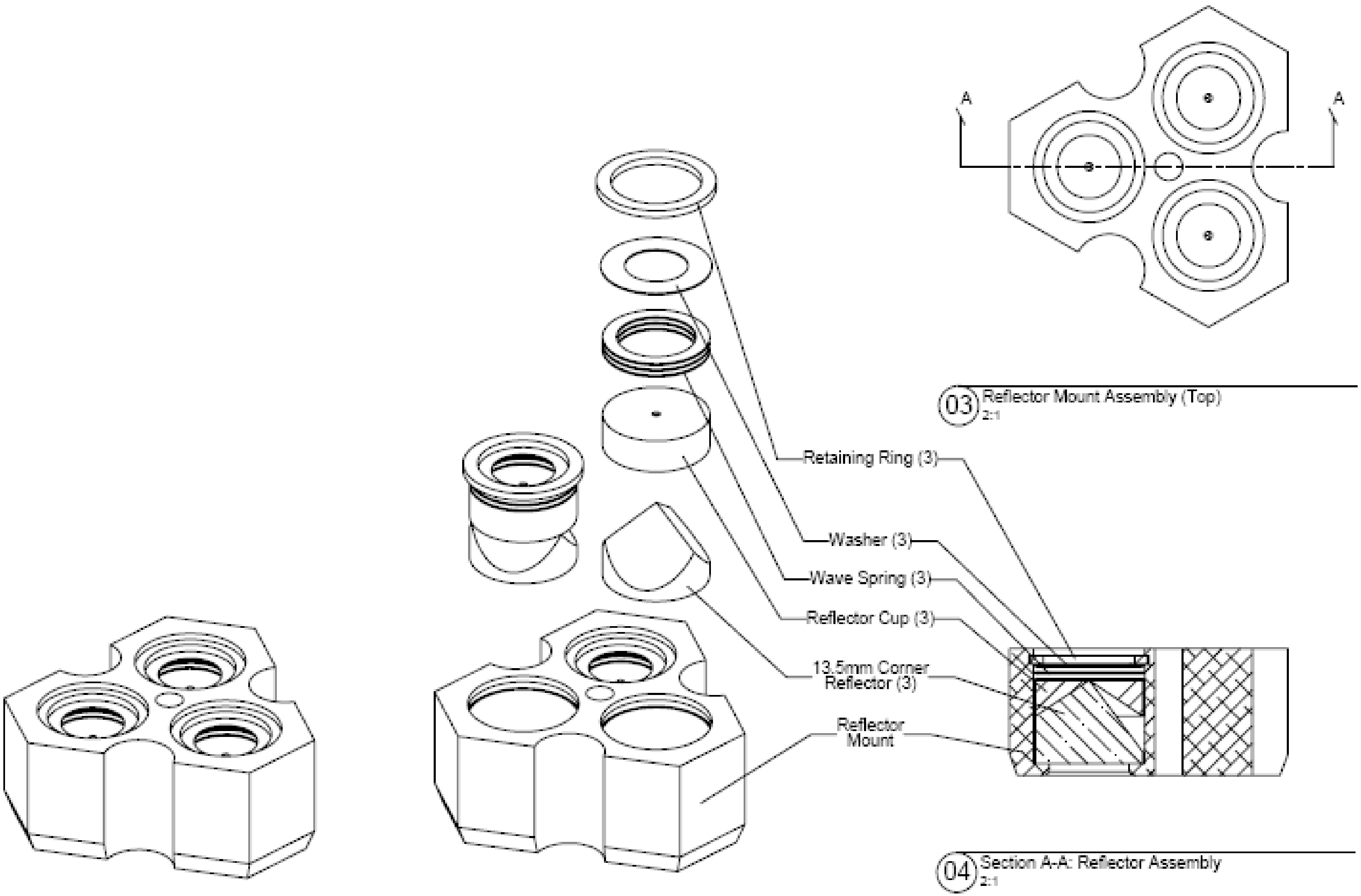
HOBERMAN

DRAFT

Corner Cube Reflector Holder



03 Reflector Mount Assembly (Top) 2:1

04 Section A-A: Reflector Assembly 2:1

01 Reflector Mount Assembly 2:1

02 Reflector Mount Assembly (Exploded) 2:1

What ILRS Can Do For PERCS?

- ILRS Can Verify Full Deployment of PERCS
  - Full Deployment Needed for Optimum HF Wave Backscatter
  - Radar Cross Section Based on Measurements of Distance between RR's at Each Vertex
- ILRS Can Detect Perturbations in PERCS Orbit
  - Collisional Drag
  - Electro-Dynamic Drag
  - High Power HF Wave Forces
- ILRS Can Measure Rotation of PERCS
  - Spin Produced by Rocket Deployment Tip-Off
  - Torque from Conducting Struts Moving Through B-Field
  - Observe PERCS Rotational Effects on Scattered Laser Intensities

PERCS Applications and Endorsements

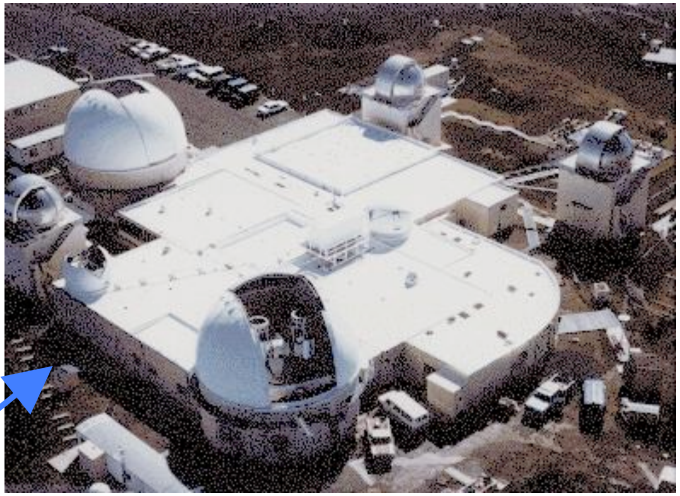
Global Needs:

- World Wide Calibration of SuperDARN
- Validation of HF Heater Patterns
- Laser Tracking and Imaging of Satellites
- Deployment of Large Structures in Space

NRL Optical Test Facility (OTF) at the Midway Research Center

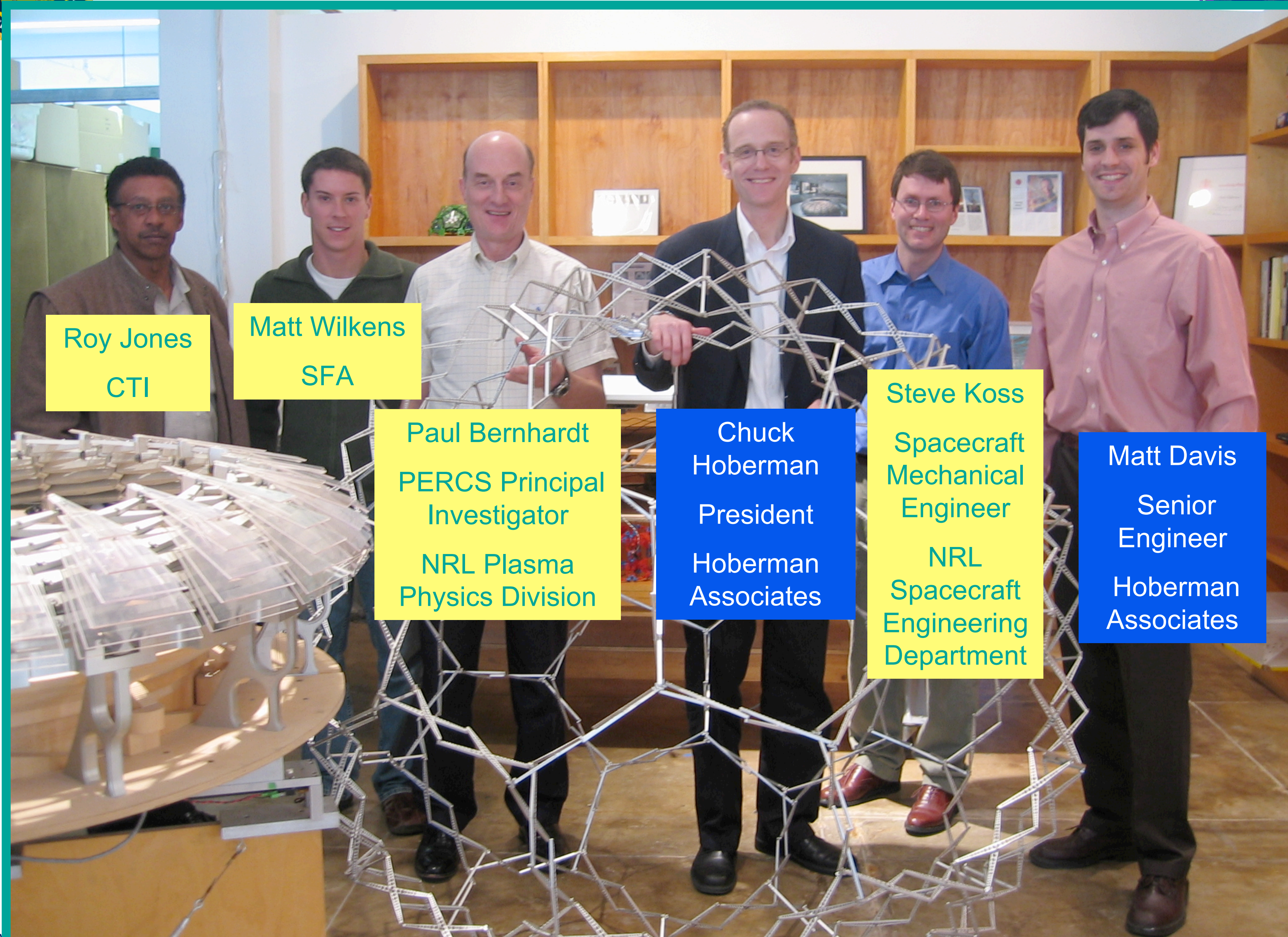
Participants

- **SuperDARN and Space Weather Radars**:
  - Richard Behnke, NSF, United States
  - Ray Greenwald, APL, United States
  - George Sofko, U. of Saskatchewan Canada
  - Terry Robinson, U. of Leicester, England
- **HAARP, EISCAT, Arecibo, SURA Heating**:
  - Craig Selcher, NRL, HAARP, United States
  - Paul Kossey, AFRL, HAARP, United States
  - Mike Rietveldt, EISCAT, Tromso, Norway
  - Michael Kosch, U. of Lancaster, England
  - MikSulzer, Arecibo Observatory, Puerto Rico
- **Optical and Laser Tracking Sites**:
  - Linda Thomas, NRL Optical Test Facility (OTF), United States
  - Haleakala Optical Sites, Jim Riker, Hawaii



Maui Optical Site (AMOS)

PERCS Design Team March 2007 with a V80 Sphere



PERCS Status

- Hoberman Associates on Contract to NRL Starting 2007
- Designs Complete (V60, V80, V180, V240)
  - V80 Usable up to 26 MHz and at 30 MHz
  - V180 Usable up to 36 and to 50 MHz
- PERCS *Radio Science* Paper January 2008
- Funding Proposal to ONR/AFOSR DURIP Through Cornell University
- US Navy Space Experiments Board Ranked PERCS for Launch 5 out of 30 Experiments
- Target Launch Date: 2011 or 2012


Naval Research Laboratory
Precision Expandable Radar Calibration Sphere
PERCS

Amateur Radio Communications with HF Signals Scattered from PERCS