electro magnetic applications, inc.

EMA Space Capabilities

Justin McKennon, Principal Scientist

CELEBRATING 40 YEARS OF INNOVATION AND EXCELLENCE

EMA ELECTRO MAGNETIC APPLICATIONS

is celebrating 40 years of innovation and excellence in EM effects to promote safety and mission success

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P-Static for Launch and Reentry Vehicles

- Launch Ranges hesitant to allow vehicles to launch that do not meet surface bonding/resistance requirements
- Impacts with water, ice and dust particles will charge isolated surfaces, leading to a discharge that would interfere with tracking radars and flight termination equipment
- EMA has a long history of studying P-Static and successfully getting permission for space vehicles to fly

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3 G.I.'s Die at German Base When Missile Catches Fire

By JAMES M. MARKHAM

Special to The New York Times

BONN, Jan. 11 — The solid-fuel motor of an unarmed Pershing 2 missile caught fire and burned in southern Germany today, killing three American soldiers and injuring seven others, the United States Army announced.

The accident was the [illegible] far involving the American-built ballistic missiles, and it seemed certain to sharpen West German anxieties over the issue of nuclear [illegible] in the country. The Pershings were first deployed in late 1983 after heated controversy in West Germany.

At a news conference [illegible], Brig. Gen. Raymond E. Haddock, the commander of the 56th Field Artillery Brigade, said the accident [illegible] at 2 P.M. when the first-stage motor of a Pershing missile was being removed from its container after [illegible] the United States.

The general, who said the fire took place in a tent at Waldheide [illegible] Heilbronn, stressed that [illegible] had not been armed with a nuclear warhead and that there was no explosion. A missile transporter and a maintenance truck were also burned, he said.

[illegible] will seek radical reductions in nuclear weapons in the imminent negotiations [illegible]

Paul H. Nitze, the special American adviser for the negotiations, was here [illegible] Government is being consulted and involved in the revived negotiations. At a [illegible] that the Pershing 2 deployment must go forward unless an agreement with Moscow made it unnecessary.

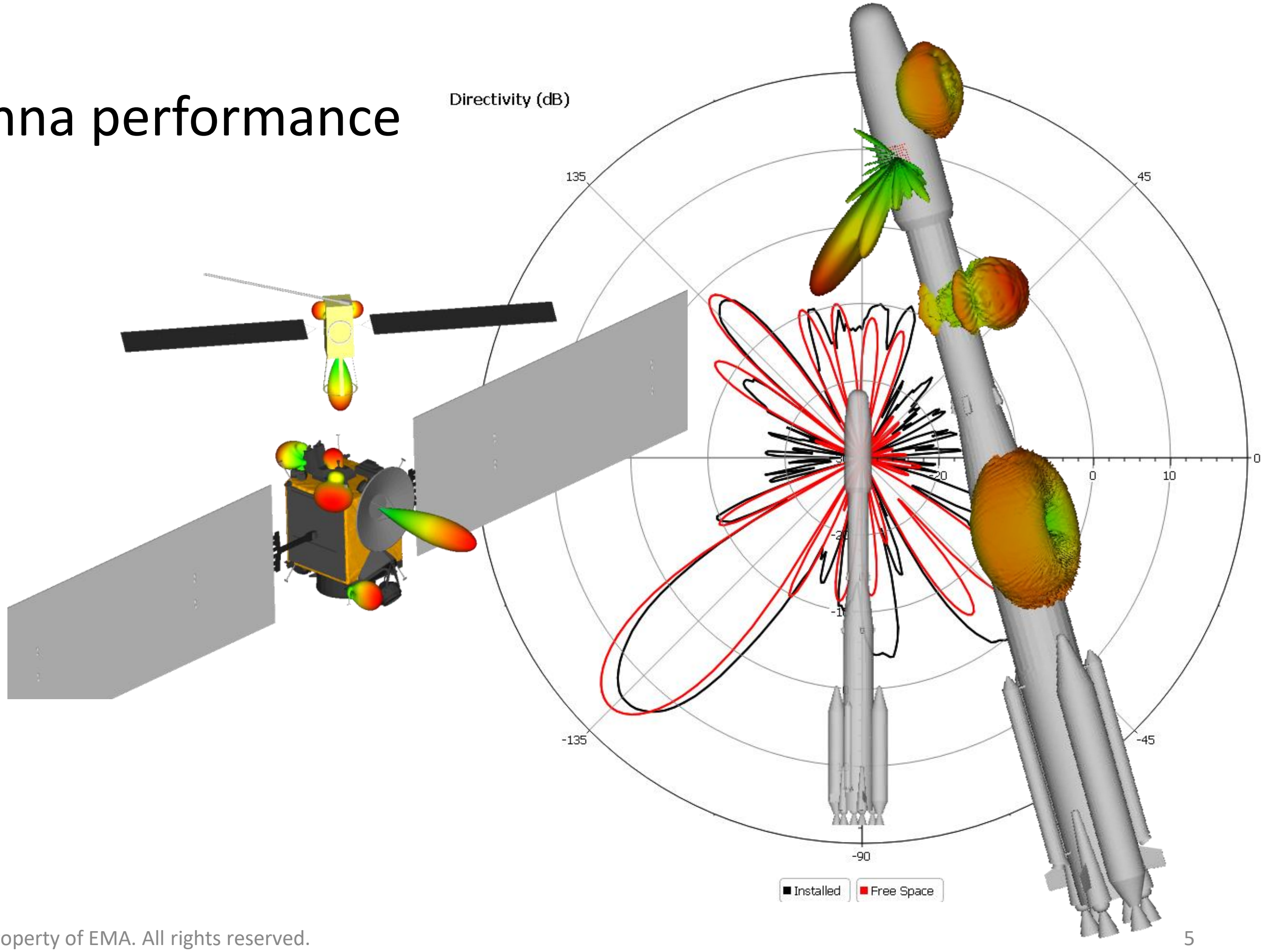
[illegible] trolled nuclear weapons — an issue that touches the question of West Germany's [illegible] ately highlighted by the reaction of the Green Party, which had campaigned [illegible] the Pershing 2's.

Lukas Beckmann, a spokesman for the anti-NATO party, demanded that [illegible] investigation into "the series of Pershing accidents" and that it "draw the consequences." Thilo Weichert, a Green deputy in the Baden-Württemberg legislature, denounced the mis-

- EMA determined the cause to be static charging of the motor case while inside its steel shipping canister. An external static discharge induced a discharge inside the propellant within the Kevlar motor case and ignited the propellant.
- EMA also helped to develop mitigation approaches to eliminate the ESD ignition process. In the following years, we also participated in two similar ESD accident investigations related to solid rocket propellant manufacturing.

Installed Antenna Performance

- Predict how platform changes antenna performance
  - Multipath
  - Diffractions
  - Creeping waves
  - Plume effects
- Impact of radomes on antennas
  - Multipath
  - Attenuation
- Impact of nearby platforms
  - Launch structure
  - Separation of launch vehicle stages



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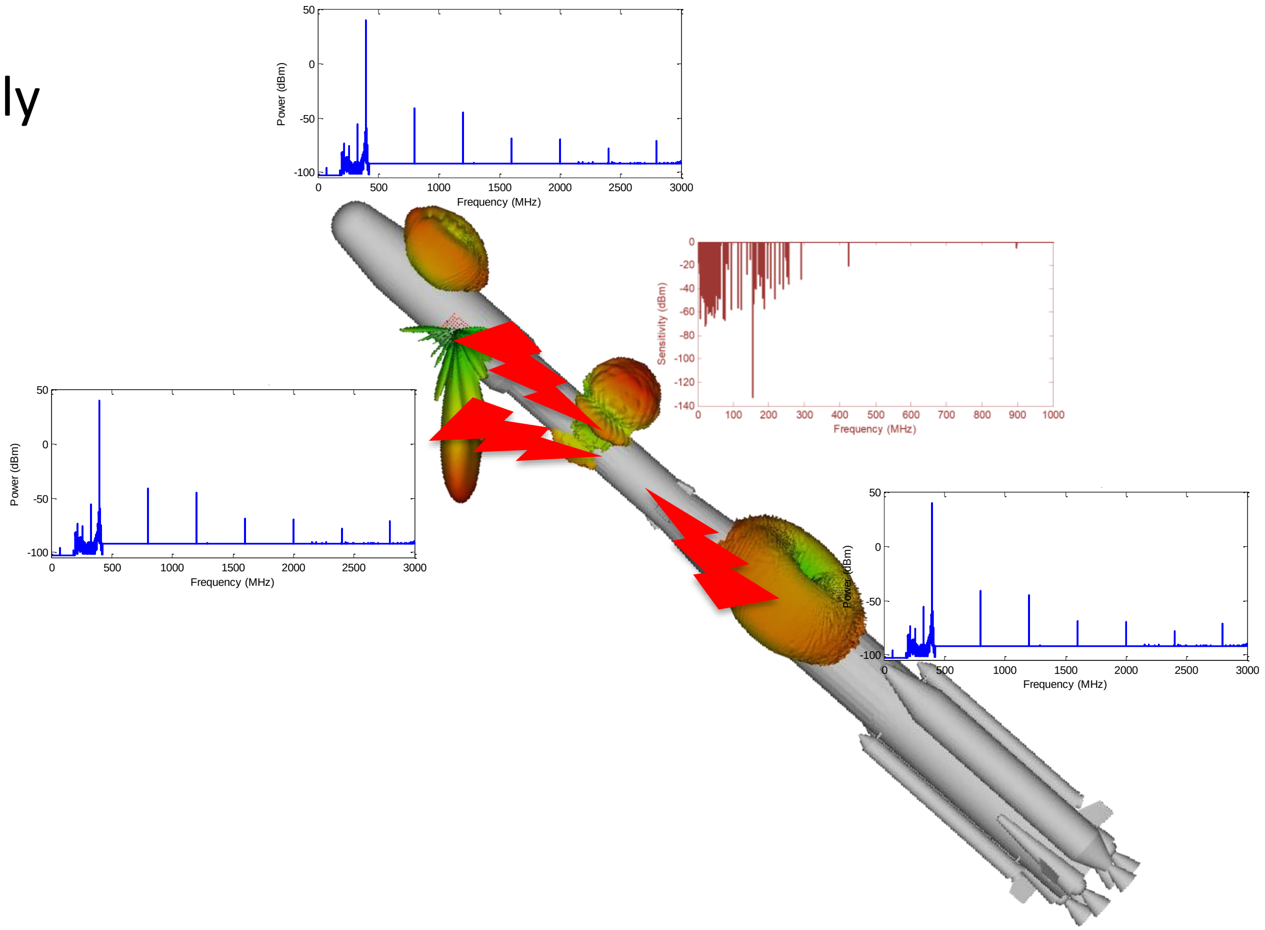
RF Interference

- Multiple RF systems operating simultaneously
- All systems must co-exist
  - No interference between systems
- Cosite analysis needs to be part of design
  - In-band and Out-of-band performance
  - Nonlinear effects (*e.g.*, intermods)
- Guide testing
  - Cosite can predict susceptible frequencies
- Multiple scenarios to consider
  - Pre-launch
  - Launch
  - Orbit



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Value Proposition

- Testing on full aerospace platforms typically occurs as the last step of the certification process
- This time period is **too late** to make the necessary design changes without a costly delay
- Companies need to accurately study performance **early** in the program when design can be impacted
- EMA routinely supports our aerospace customers to ensure that certification is met and solutions delivered on time

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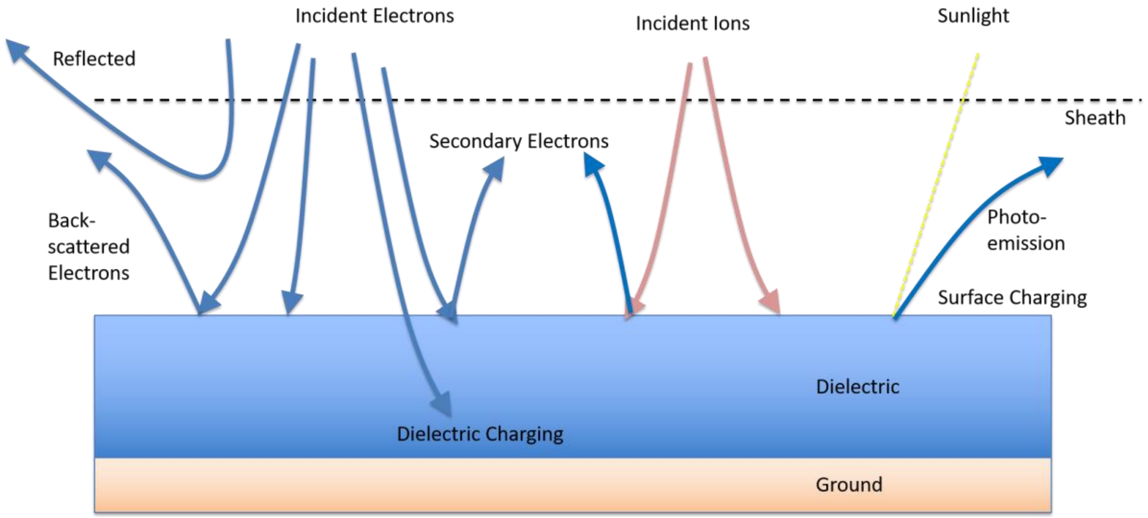
Background

- Electric charging due to charged particles in space is an important environmental risk for the satellites, spacecraft, and other devices
- The figure below illustrates the dynamic: incident particles (mostly electrons) penetrate within low conductivity materials, creating electric fields that may result in electrical arcing
- Arcing can damage materials or create electromagnetic interference for antennas and electronics



Capabilities and Expansion

- Non-Ionizing radiation is widely recognized as one of the biggest causes for performance degradation, damage, and mission loss of all space related effects
- Objects in space that intend on operating in this environment for any appreciable amount of time need to be capable of tolerating these harsh environments
  - High energy electrons, protons, VUV radiation, etc.
- Many complex physics at play, and different materials respond very differently to this environment
  - RIC – insulators can become conductors
  - Arcing, ESD, punctures
  - Single event upsets from high energy particles
  - Biasing (eclipse, eccentric orbits, forced current flow)
- Failure to adequately understand and analyze how materials will perform in this environment **will** greatly reduce survivable lifetime, operational capability, and can ultimately result in costly mission losses

EMA Space Plasma Capabilities

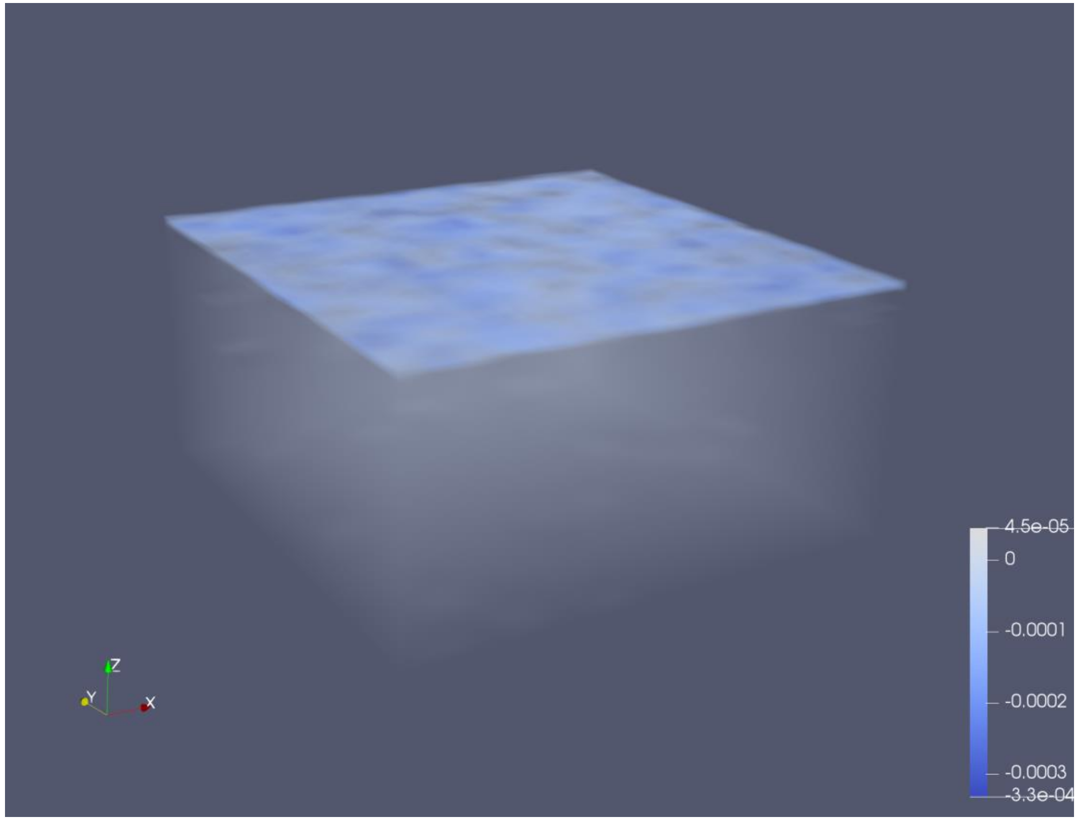
- Space Plasma and Spacecraft Interaction Leadership:
  - NGC Mission Extension Vehicle
  - LMSS NASA Orion
  - SpaceX Starlink
  - SNC DreamChaser
  - JH APL Europa Clipper
- Simulation
  - Developed EMA3D-Internal multi-physics commercial product for energetic electrons and System Generated Electromagnetic Pulse (SGEMP)
  - Developing EMA3D-Charge, a fully coupled Surface and Internal charging commercial software product
- Experiment
  - Building Spacecraft Charging and Environmental Effects Chamber (SCEEC) for material characterization, radiation survivability, and complex environment replication
  - Additional chambers planned for plasmas, atomic oxygen, and other key capabilities in coming years

EMA Today

- EMA is a key partner of Sierra Nevada Corporation (Dream Chaser's Dream Team)
- Lead for electromagnetic compatibility
- Simulation and testing support for the last five years

Capabilities and Expansion

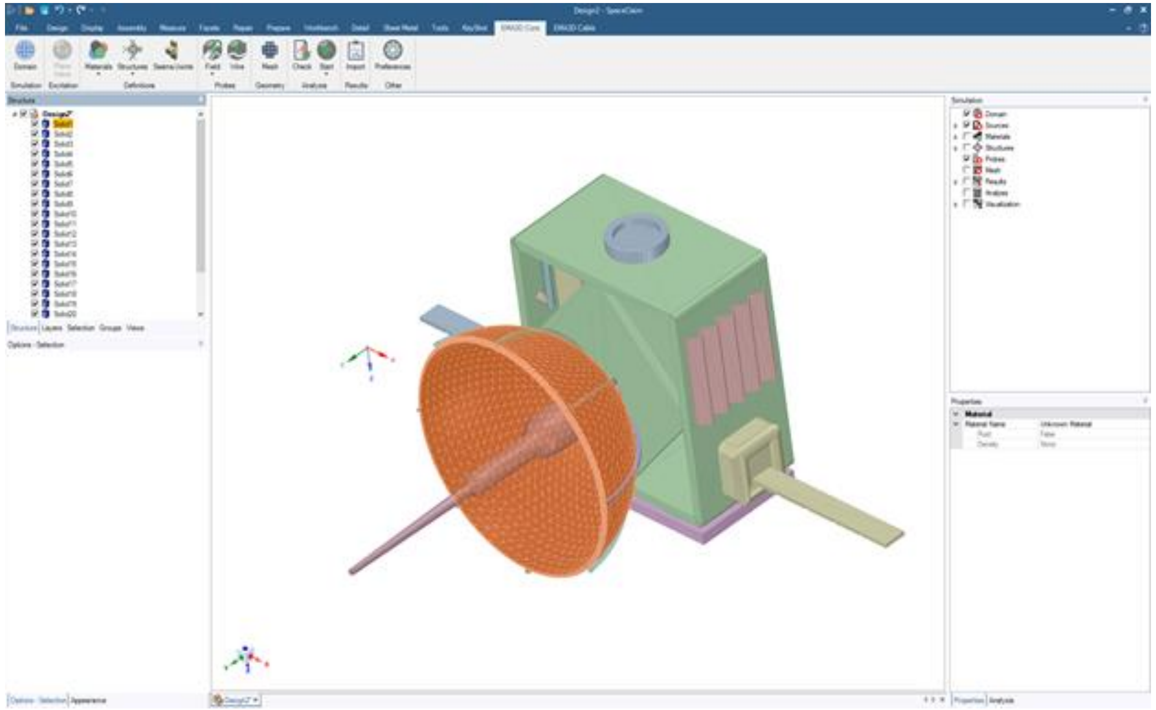
Current capabilities:
- EMA's expertise is in non-ionizing radiation
- This environment comprises the plasmas, electrons, and other particles that spacecraft, satellites, etc. encounter in various orbits or parts of space (LEO, GEO, etc.)
- EMA has considerable simulation capability currently, via EMA3D Internal, and coupled simulations
    - Internal charging and particle transport



Charge Density in an insulator with 5mil of Al shielding

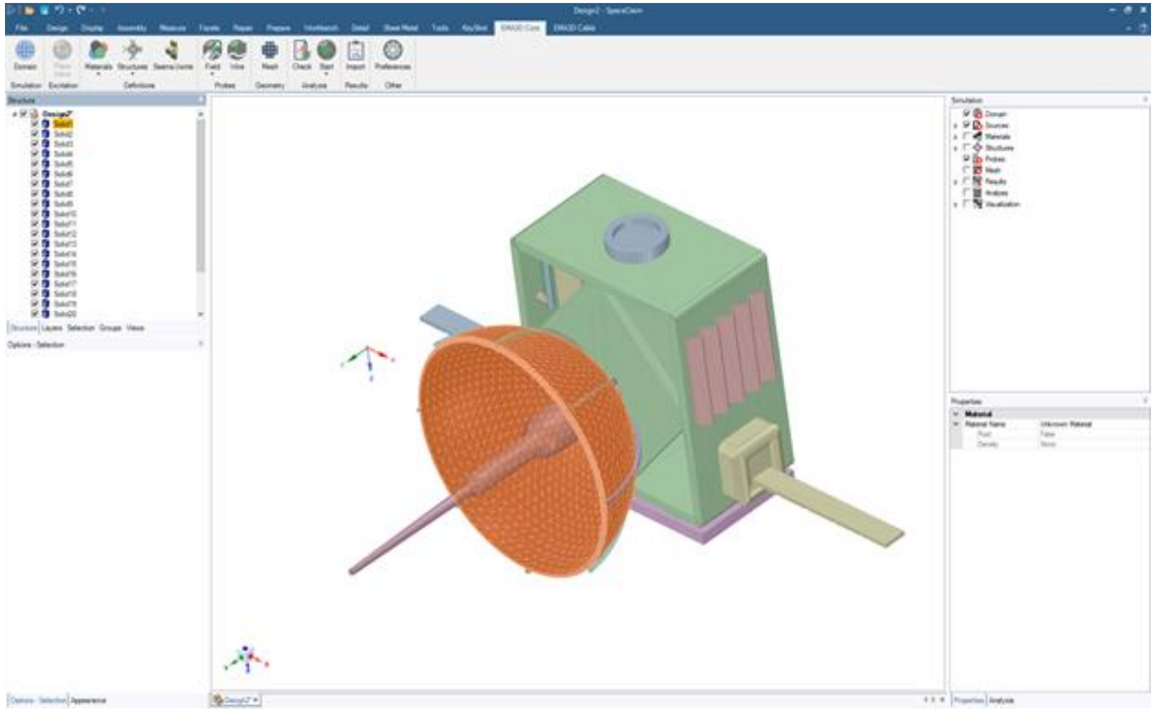
Simulation Environment

- EMA3D-Charge will fix all of the existing challenges that the currently available tools present
  - Approximations (inaccuracies)
  - Problem size limitations
  - Usability (requires dozens of file exports and imports between multiple software environments and iterations to solve even simple problems)
  - Simulation tool will couple the various physics timescales into a modern user interface to allow for engineers and companies to accurately solve spacecraft charging and space weather related problems
  - This **cannot** be done without a chamber to validate the calculations

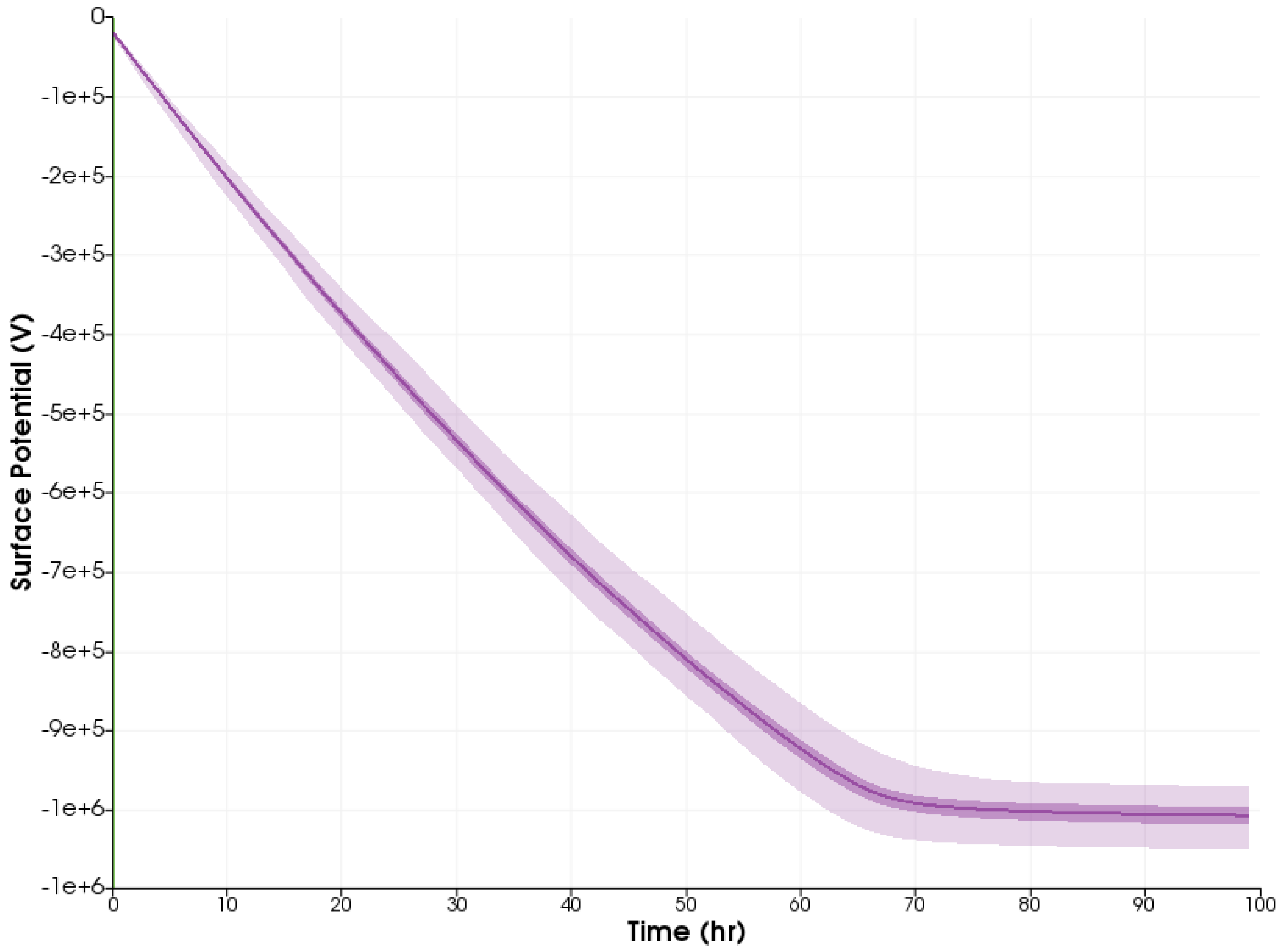


Simulation Environment

- Biggest feature is the coupled surface/internal interface
- Both effect one another, and the time scales at which each phenomena occurs is vastly different
- Making this tool usable by engineers (rather than needing an entire year of study and practice to use it) is also a major goal of this project
- CAD cleaning/defeaturing
- Custom materials
- Access to a materials database



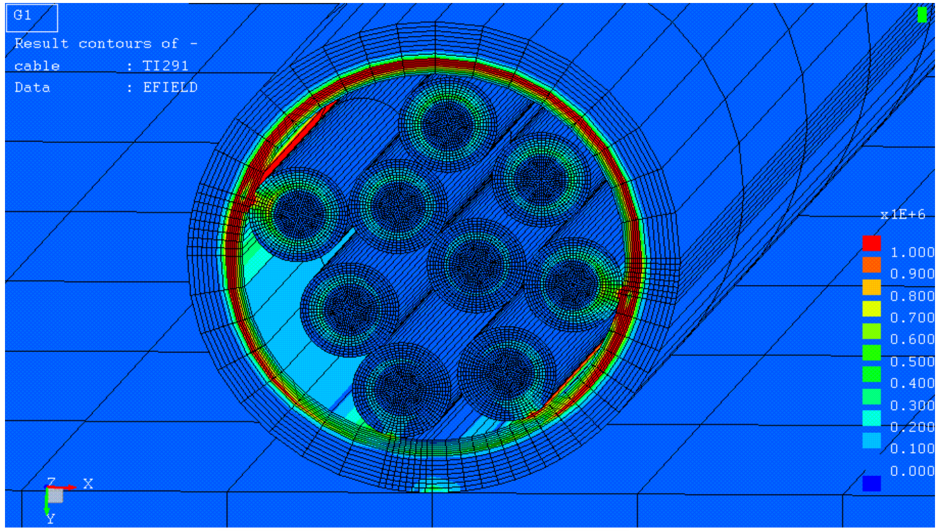
Capabilities and Expansion

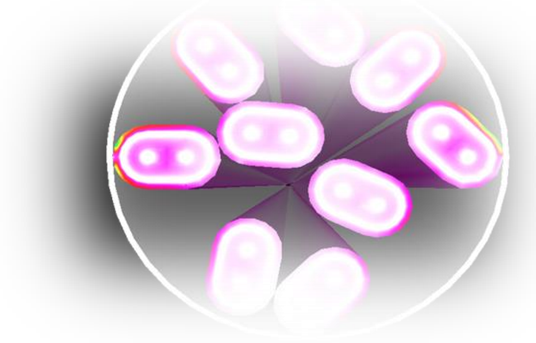


- "Hard coded" partial version of EMA3D-Charge is currently in use internally, but not distributable yet
- 1 MeV electron beam is incident on a planar insulating surface
- Graph shows that the material charges to the beam energy, and then begins deflecting incoming electrons

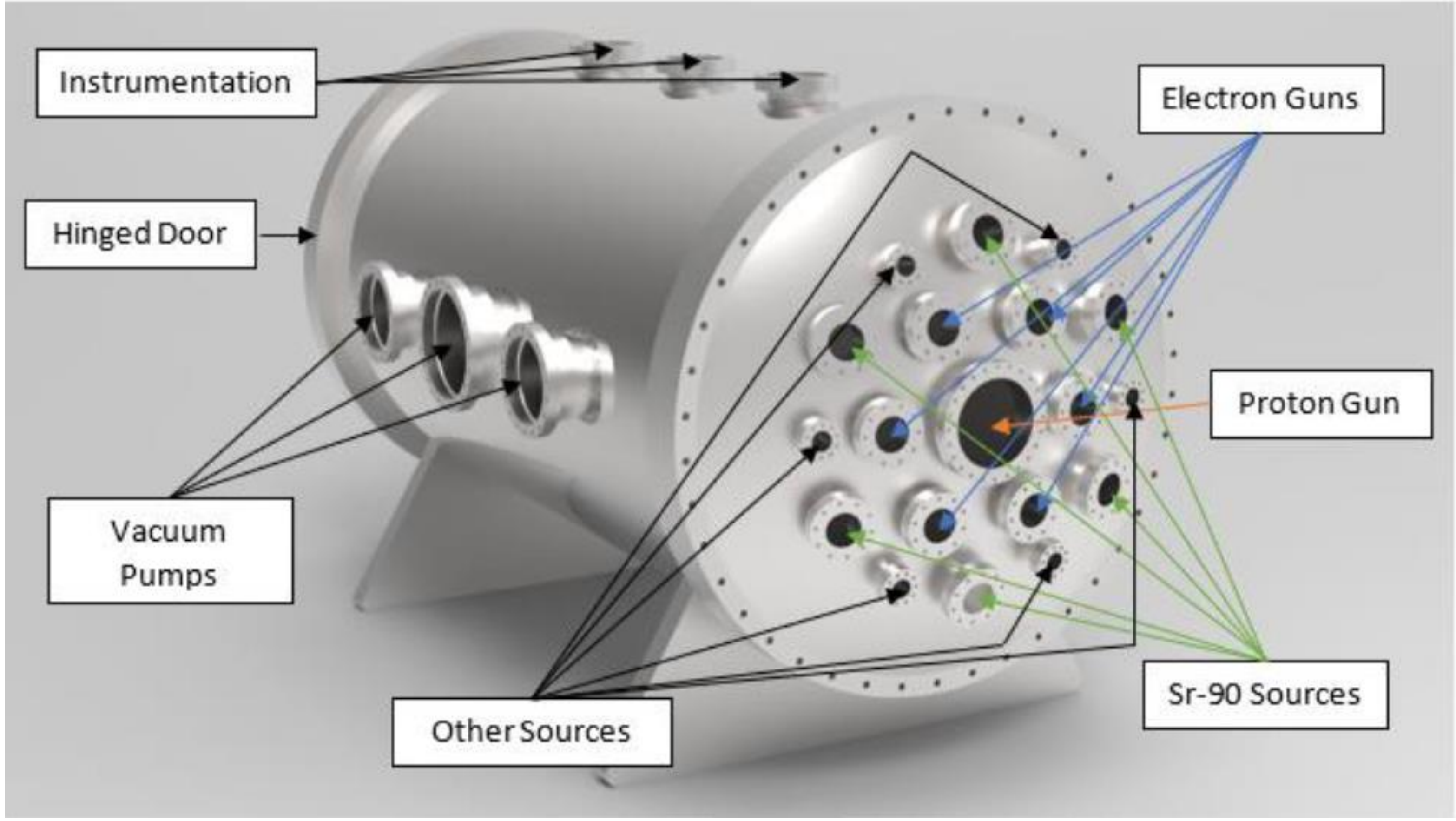
EMA3D-Internal: SGEMP for Cable Transients

- EMA3D-Internal provides a consistent framework for evaluating the coupling of external radiation sources to cables and extracting transients for design
- Within EMA3D-Internal:
  - Geometry is developed, including native CAD import
  - Many source particle types and source geometries are supported
  - Simulation couples particle transport and full-wave electromagnetic FEM solver
  - Shield and conductor level transients are easily extracted from post-processing
  - Pin level transients can be further examined within MHARNESS or LTspice, for example
    - Shield currents serve as a source for MHARNESS



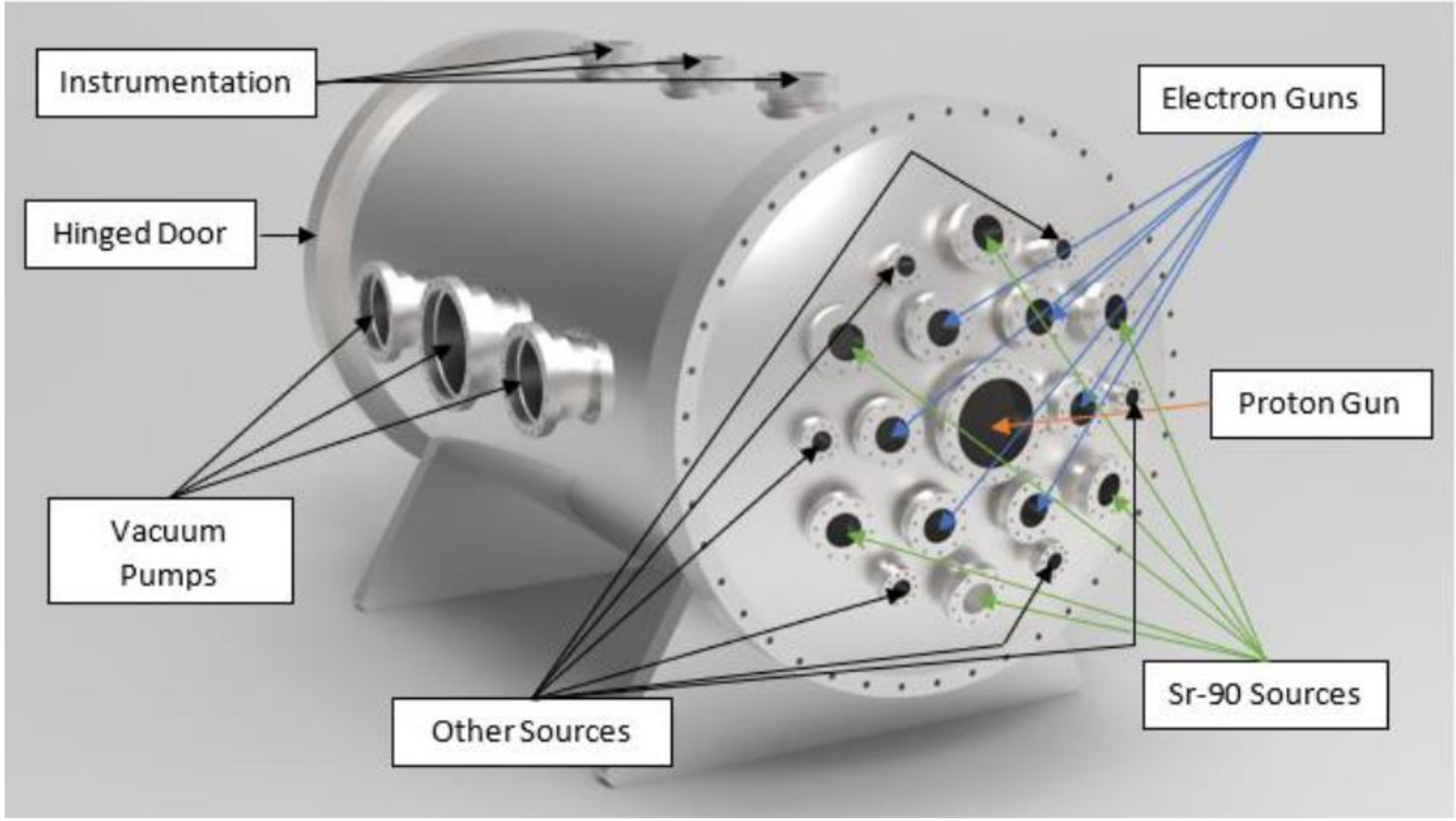


Test Environment



- Common Flange Interface (CFI)
- CFI will allow for the moving and reconfiguring of sources to replicate complex and unique environments, and other future/new sources
- Stepper tracks inside chamber for controlled sample configuration

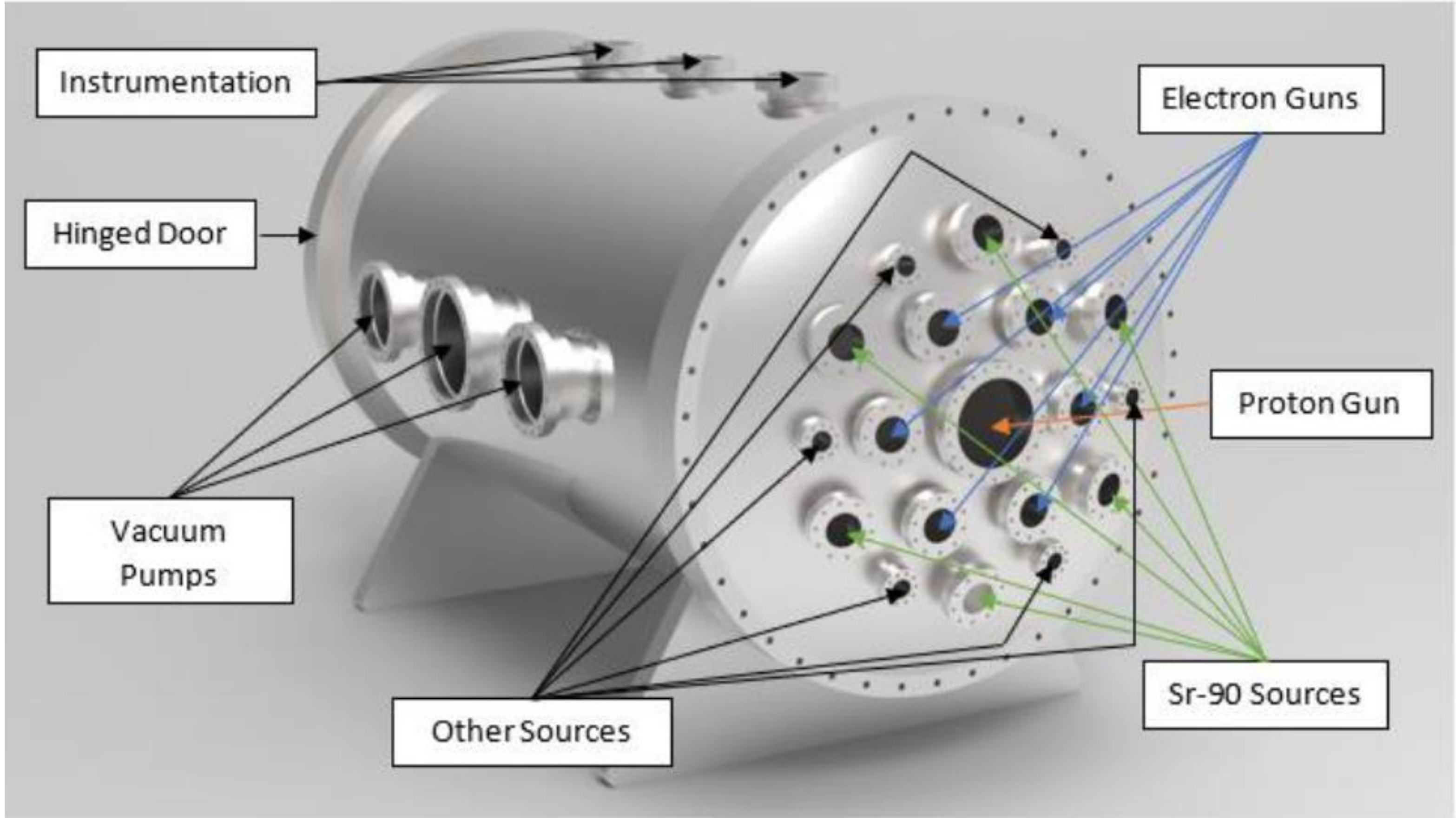
Test Environment



Each flange interface will be connected to a controlled shuttering mechanism. The shutters will allow for the environment to be changed in-situ during testing, which allows for different scenarios to be evaluated

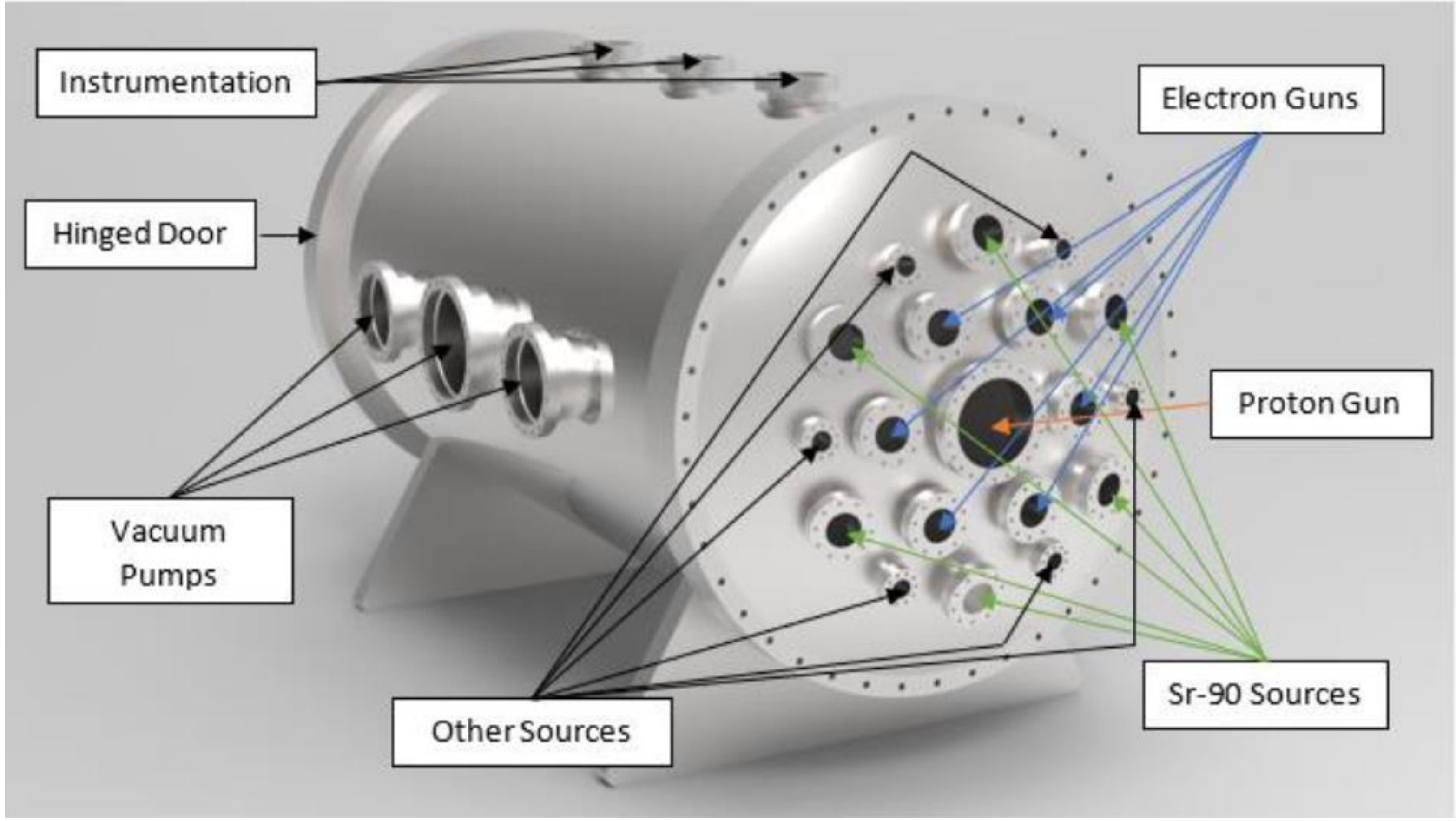
This dynamic environment is a significant difference between this chamber and all existing chambers

Test Environment



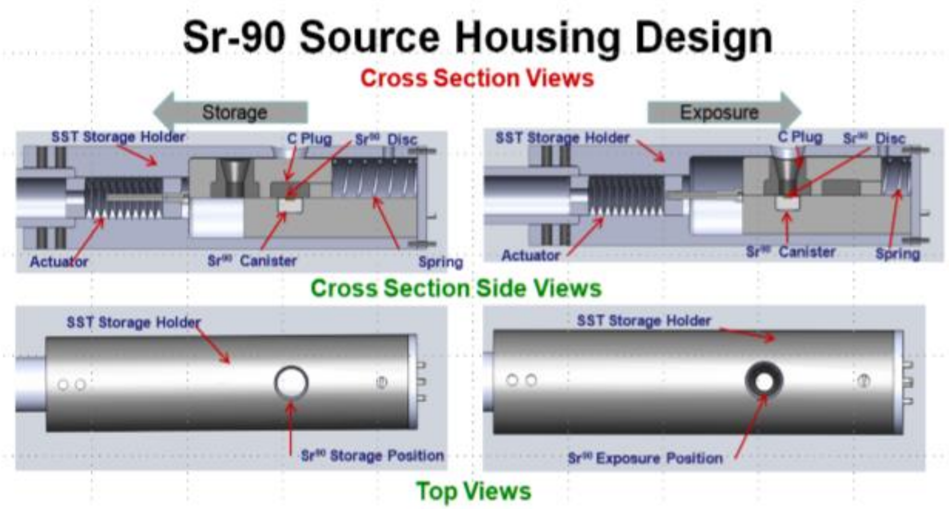
- Low, Medium, and High energy electron sources (5keV – High Energy (next slide))
- 100keV protons
- Solar simulators – xenon lamps, and internal LED ring (3 sun)
- Fluxes ranging from 1nA/cm^2 – 500nA/cm^2

Test Environment



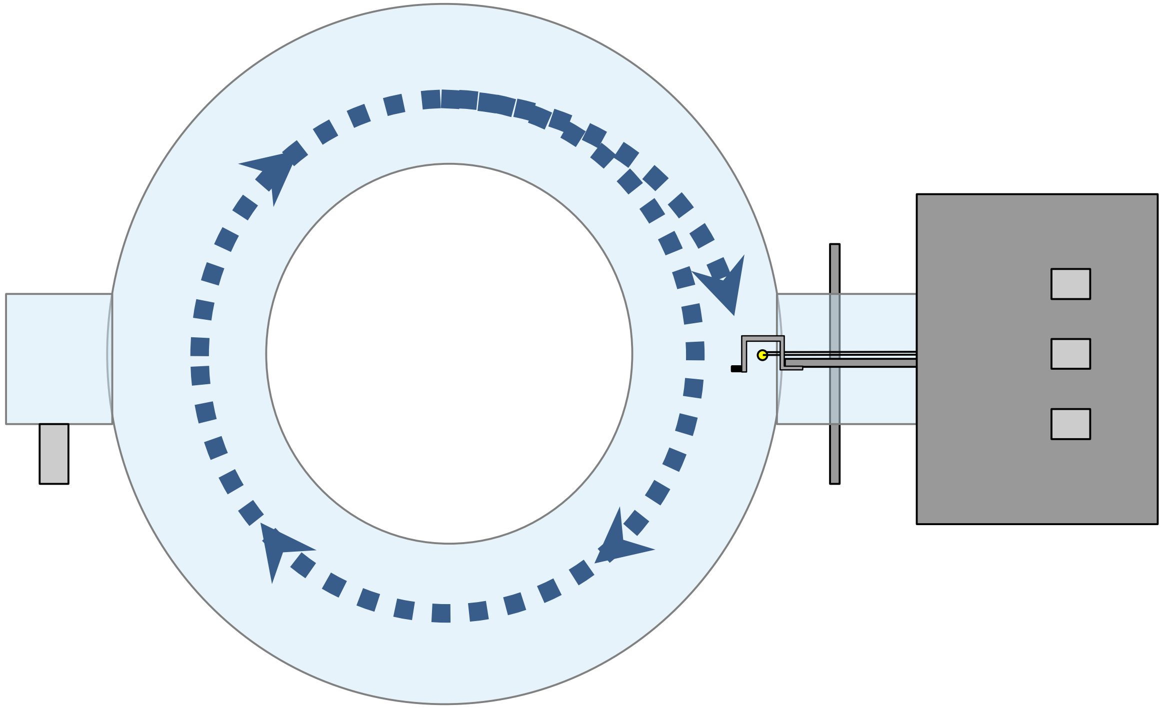
- Faraday cup
- Langmuir probe
- Surface voltage probe
- Video arc detection
- Spatial arc detection
- Spectrometer
- Vacuum transfer system for charge storage
- I/O to support powered system testing

Test Environment – High Energy Electrons



1-3 MeV

Or a custom Betatron



5-9 MeV

Industry

- Utah State University, Air Force Research Lab (Space Vehicles Directorate) and Marshall Space Flight Center are supporting the development of EMA3D-Charge and the chamber
- EMA leads the industry's standards work for space
    - Chair of the Commercial Space Committee for the SAE – Justin McKennon, Chair of the Space effects working group is Greg Wilson
- Current focus is on developing a modern performance standard for demonstrating tolerance/survivability
- Simulation and testing encouraged, but process based
- Committee has heavy industry participation from NASA, other major launch companies, etc.
- Rigor is needed to ensure failure modes and part performance is understood, and eventually to reduce rework from suppliers so that parts can be "certified" to meet certain performance criterion at various orbits and environments