



Integrity ★ Service ★ Excellence

SOARD

Research Portfolio

AFOSR Spring Review

March 2013

James Fillerup, PE, Director

**Southern Office of Aerospace
Research and Development**

Air Force Office of Scientific Research

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SOARD - Smallest of Int'l Offices



**Two Project Officers cover
a broad range of scientific disciplines**
(rule of thumb: if a topic of the AFOSR BAA - check it out)

FY12: 42 projects / 33 Institutions



- **Primary focus - Fillerup**
 - Space Sciences
 - Material Sciences
 - Structural Mech / Aerodyn



- **Primary focus - Pokines**
 - Nanomaterials
 - Bionano
 - Aero morphing systems

SOARD (2009)
Santiago, Chile

City locations of research partners

SOARD relies on AFOSR POs expertise.



Briefing Contents

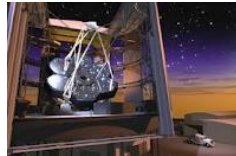


- **Space Science Portfolio**
 - Solar, Ionosphere, Magnetosphere (Kent Miller (AFOSR), RV)
- **Molecular Physics**
 - Isotope Decay Project (Tom Hussey, John Luginsland (AFOSR), Maj Robert Lee, (USAFA))
- **Material Science**
 - Ferroelectric Nanoparticles (Charles Lee (AFOSR), Dean Evans (RX))
 - Extremophiles: Synthesis of Se nanoparticles (Hugh DeLong (AFOSR))
- **Structural Mechanics**
 - Filament Wound Structures (Matt Triplett, (Army ARDEC), Dave Stargel (AFOSR))
- **Aerodynamics**
 - Stability of Coaxial Jets (Ivett Leyva (RQ))



Space is Big in So. Am.

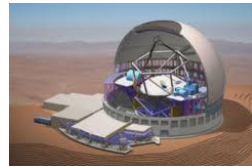
Astronomical Observatories - Chile



Las Campanas Observatory
(Carnegie)



Gemini Observatory
(Int'l partners - twin telescope in Hawaii)



Cerro Tololo Observatory
(NSF)



Alma Radio Observatory
(Several Int'l partners)

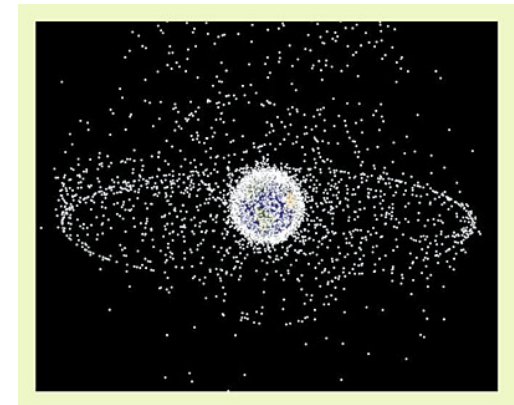
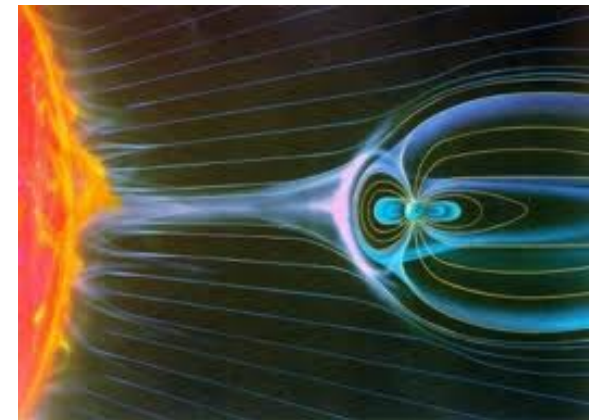
Chilean researchers get 10% of time - no charge
Created strong Univ. Astrophysics Departments



AF interest in Space Science



- **Forecasting the geospace environment of Earth, for Space Situational Awareness**
 - Solar Physics
 - Magnetospheric Physics
 - Ionospheric and Thermospheric Physics
- **Necessary for:**
 - Satellite drag predictions
 - Radiation belt perturbations
 - Communications/navigation/surveillance



So. Am. partnerships provide access to southern hemisphere skies



Solar Physics Research

Leoncito Astronomical Complex – Argentina



Solar Observatory Facility

Facility owned by Brazil - Operated by CASLEO

The Search For New Approach To Detect
Solar CME Precursors At Sub-THz And
Mid-IR Frequencies



CASLEO Observatory Complex

Collaborators:

- AFOSR / RV, US
- University Mackenzie, Brazil (Lead PI: Pierre Kaufmann)
- UNICAMP, Brazil
- USP, Brazil
- CASLEO, Argentina

Supporting agencies

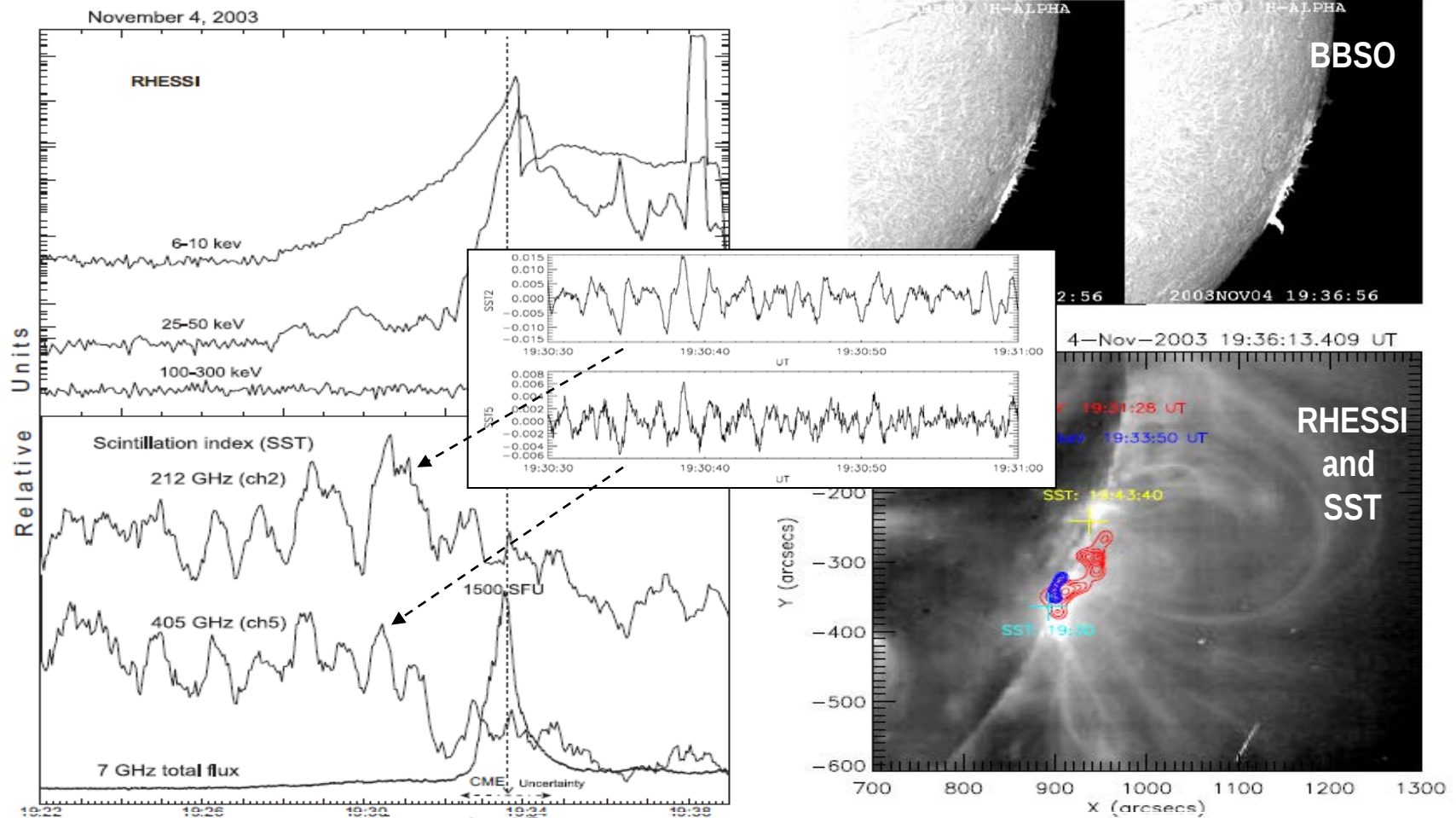
- FAPESP, CNPq, Brazil
- CONICET, Argentina
- AFOSR, US



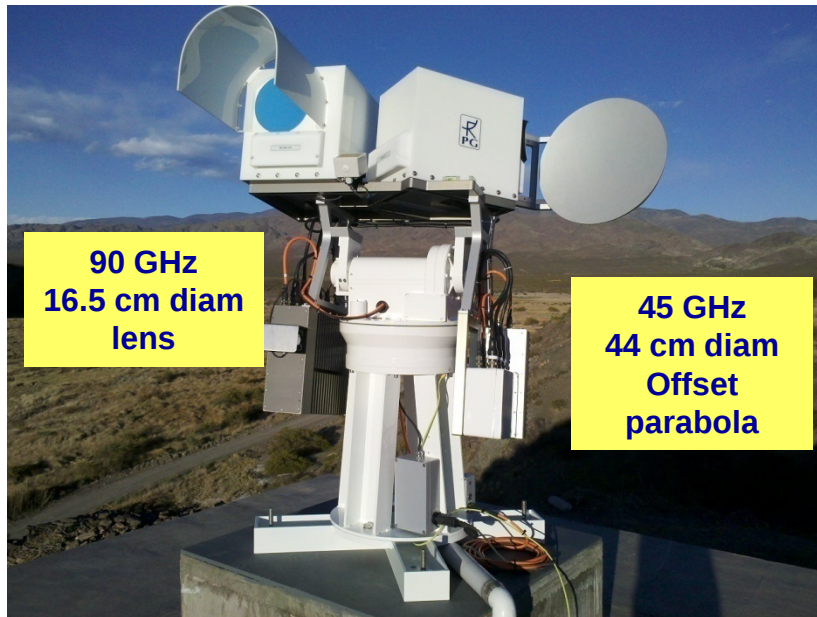
Solar Physics



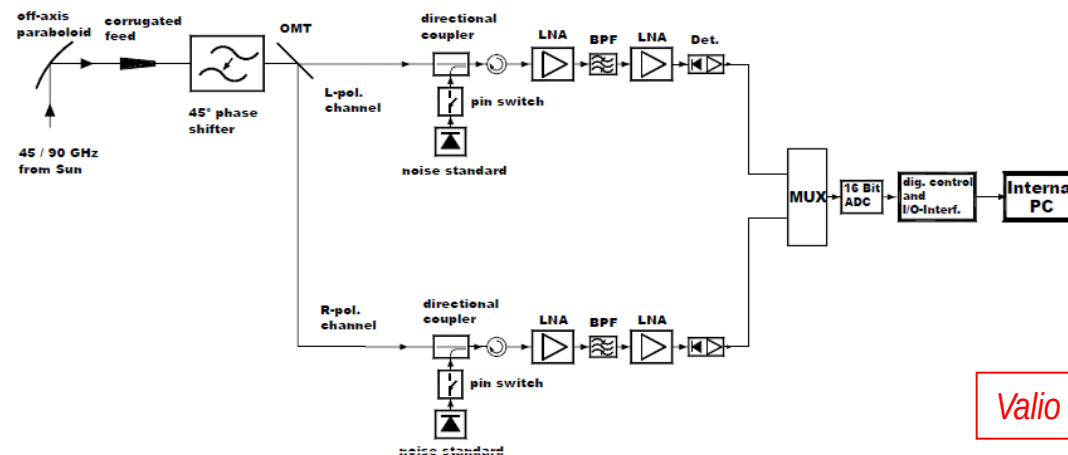
Submm-w 2 sec pulsations maximize with CME launched nearly 10 min before large flare onset!
Kaufmann et al., Solar Phys. 2012



Solar Circular Mm-w Polarization Patrolers (Operations at CASLEO started November 2011)

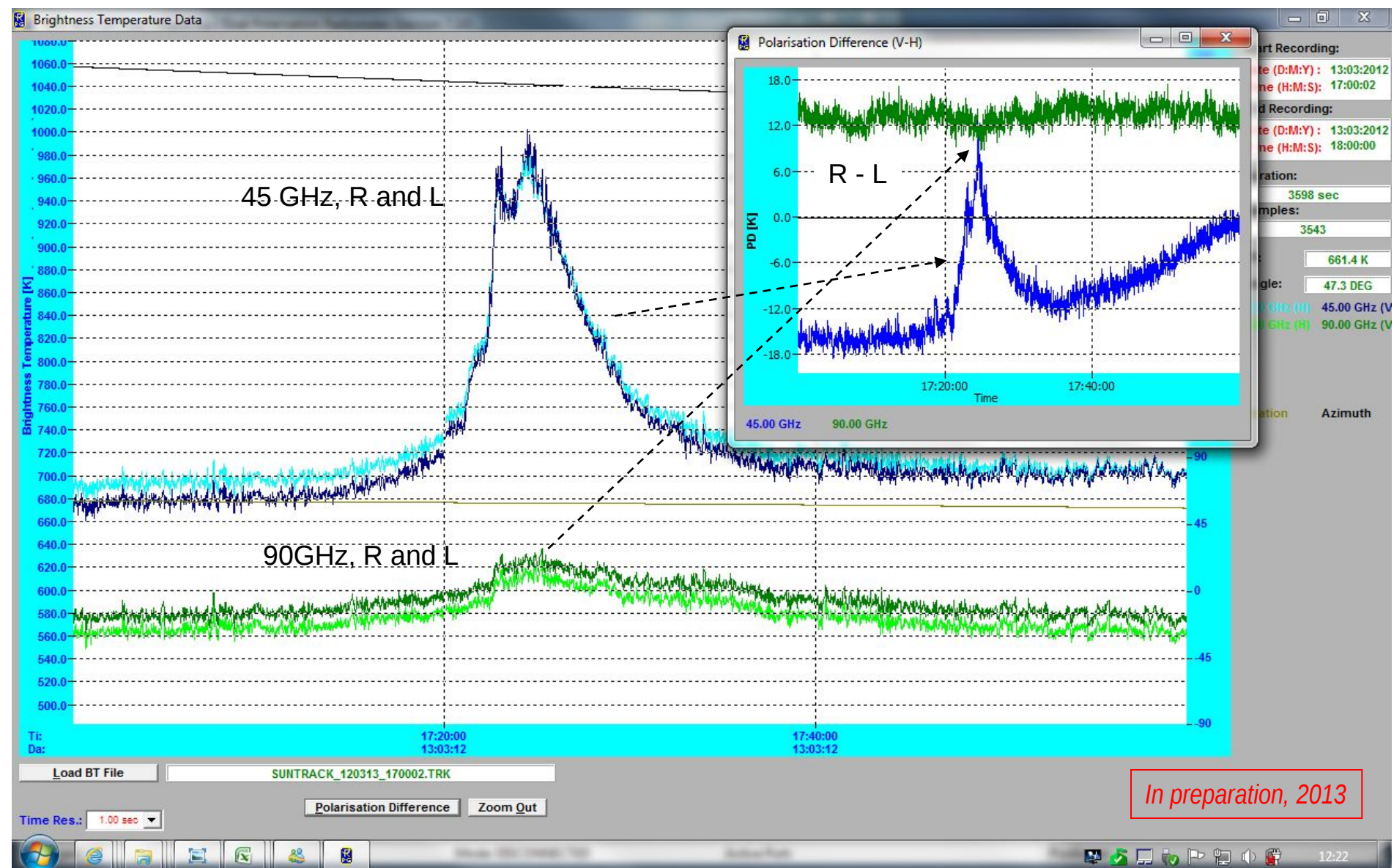


Covers the spectral frequency gab from 20 to 200 GHz



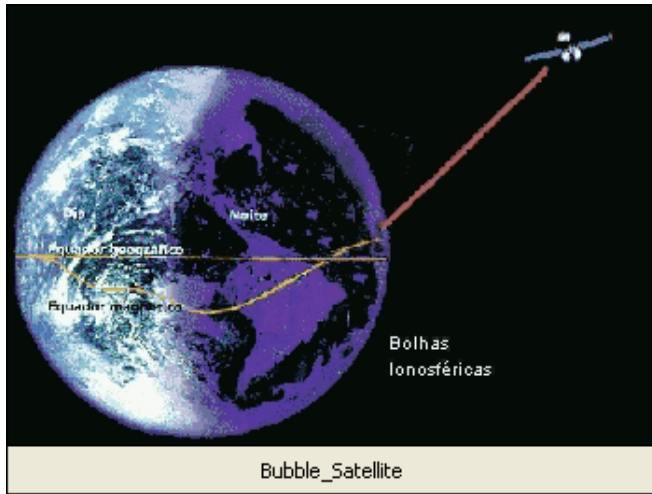
Valio et al., Solar Phys. 2013

13 March 2012 solar burst – also observed at 200 GHz, 30 THz, H α at El Leoncito;
by AFRL RST microwaves and by SDO – currently under joint investigation





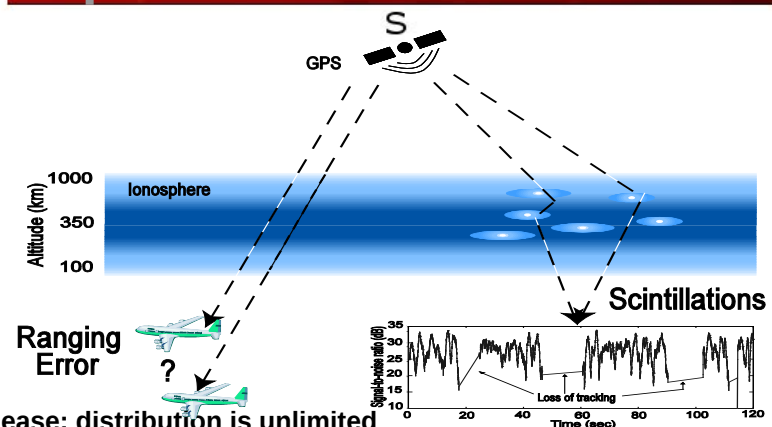
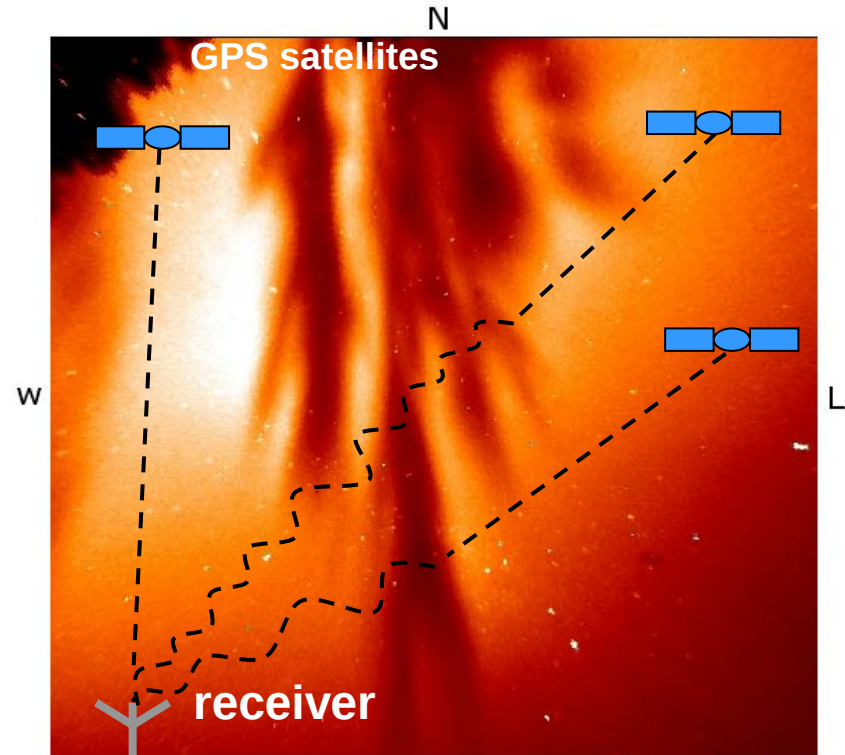
Ionosphere Research with Brazil



The Problem:

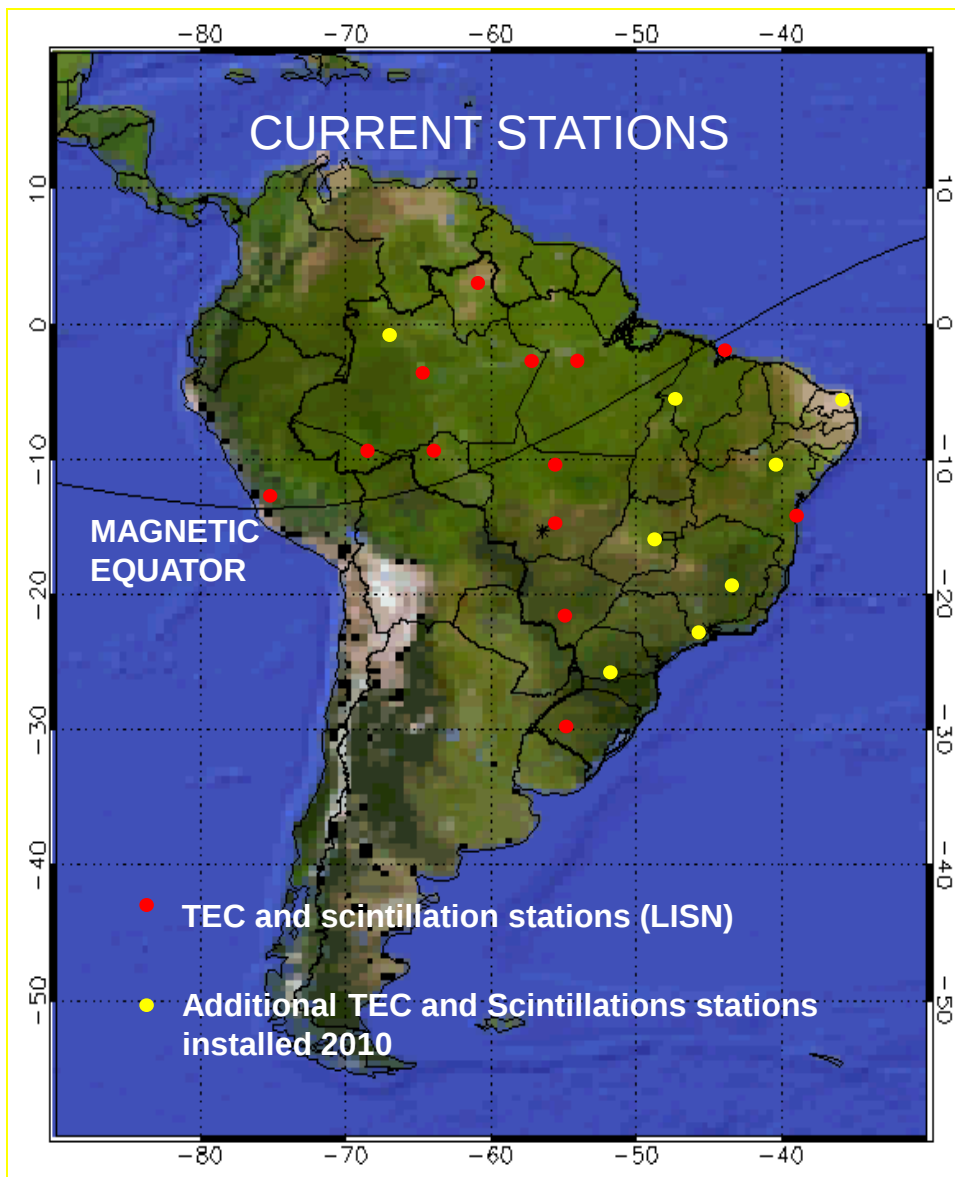
Ionospheric bubbles are rarefied plasma regions. Ionospheric irregularities inside the bubbles have scale size varying from cm to km.

The amplitude fading (scintillations) if deep enough and long enough, can potentially cause tracking loss.





Data Collection Stations - Brazil



GPS scintillation stations in Brazil

LISN / NSF

Santa Maria-RS,
Porto Velho-RO
Rio Branco-AC
Parintins-AM
Tefé-AM
Boa Vista-RR
Dourados-MS
Santarém-PA
Alta Floresta-MT
Ilhéus-BA
Cuiabá-MT
São Luís

Additional Stations (2010):

Belo Horizonte MG
Brasília
Natal RN
Pato Branco PR
Imperatriz-MA
Petrópolis-PE
São José dos Campos SP
São Gabriel da Cachoeira AM

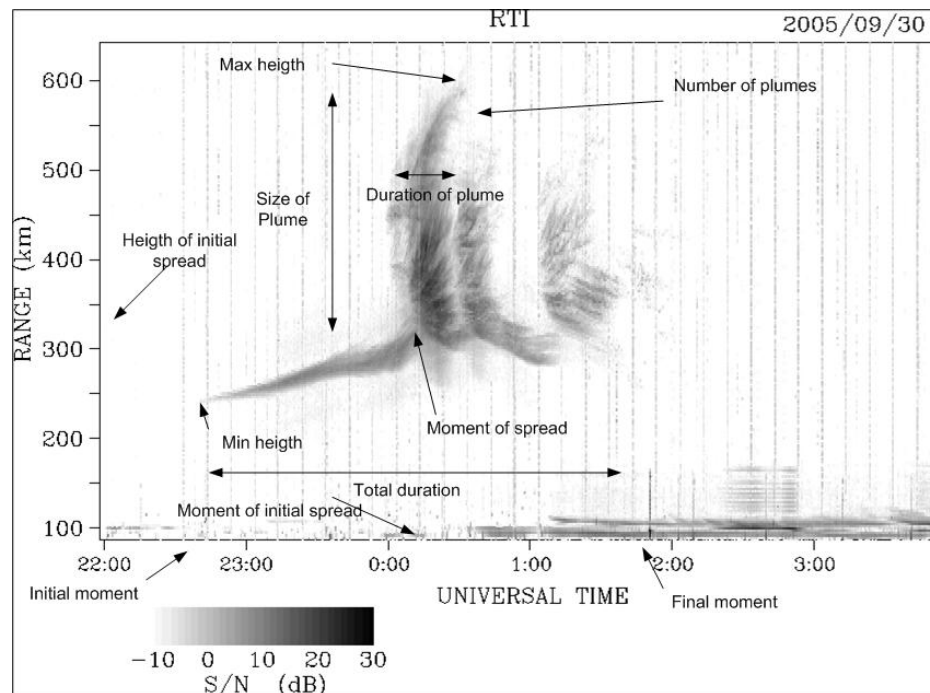
Also LISN station at Alcon, Peru

Project: “Ionospheric Irregularities
Predictions and Plumes
Characterization for Satellite
Data Validation”

PI: Eurico de Paula, National Institution
for Space Research (INPE)



São Luis Station, Brazil



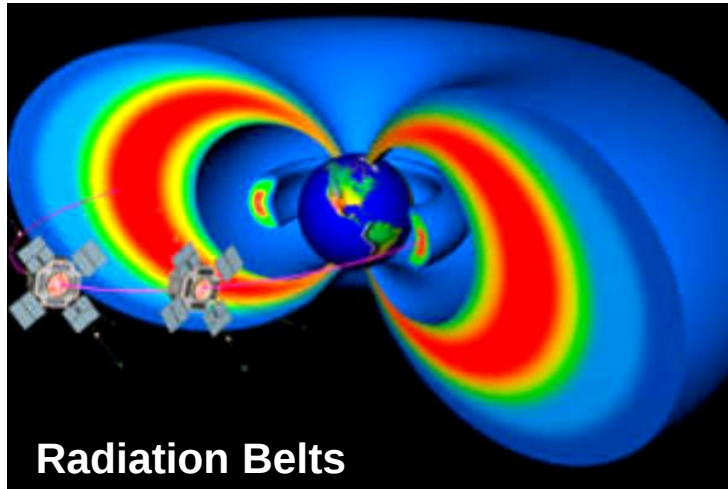
Example: São Luis VHF incoherent scatter radar plumes analysis
GPS antennas at São Luis during the AFRL/INPE campaign
(installation on February 2008)

Cooperation in Atmospheric, Ionospheric and Magnetospheric Research MOU.

- MOU signed in June 2001. SAF/IA is in process of negotiating a new MOU.



Magnetosphere Research



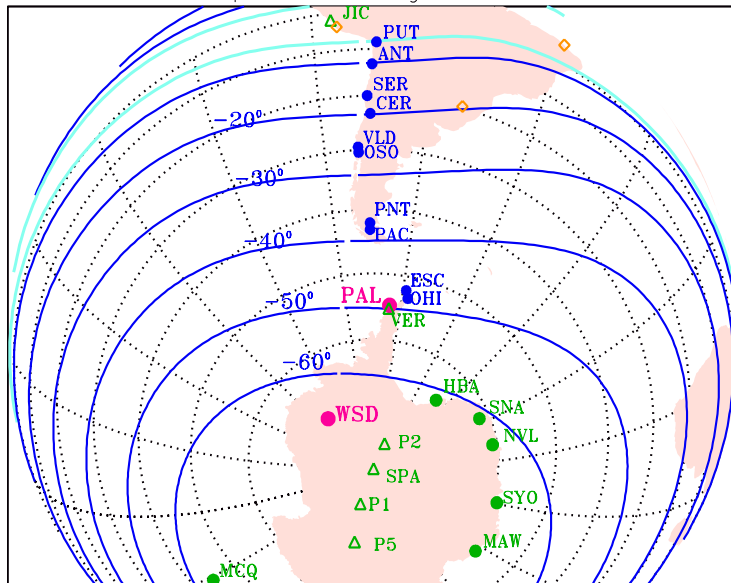
Radiation Belts

Objective: Study of geomagnetic phenomena (i.e., magnetic storms) and processes that affect particle fluxes in the radiation belts

Collaborators:

- **US:**, NASA, RV, Boston College
- **Chile:** U of Santiago, (Lead PI: Stepanova), U of Chile, U of Concepcion

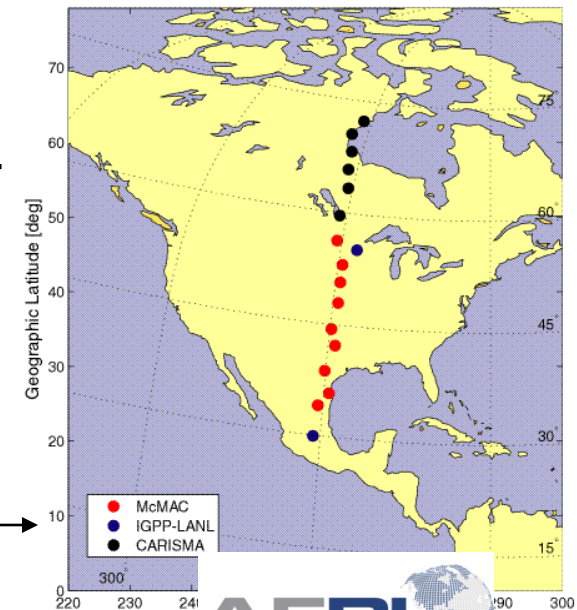
Map of SAMBA magnetometers



Magnetometer Monitoring Stations

← SAMBA Stations
(in Chile)

McMAC
IGPP-LANL
CARISMA
→





USAFA SSA Tracking Telescope in Chile



Mamalluca Observatory
Future site of USAFA tracking telescope



Proposed FTN Station and 50 cm telescope

USAFA Falcon Telescope Network (FTN) For SSA

- Space Situational Awareness (SSA) - To detect, track, identify, image, predict future positions of space objects
- A network of remote telescopes with one located in Chile providing access to southern hemisphere

Collaborators

- USAF Academy
- AFOSR / RV
- Universidad of La Serena
- Mamalluca Observatory

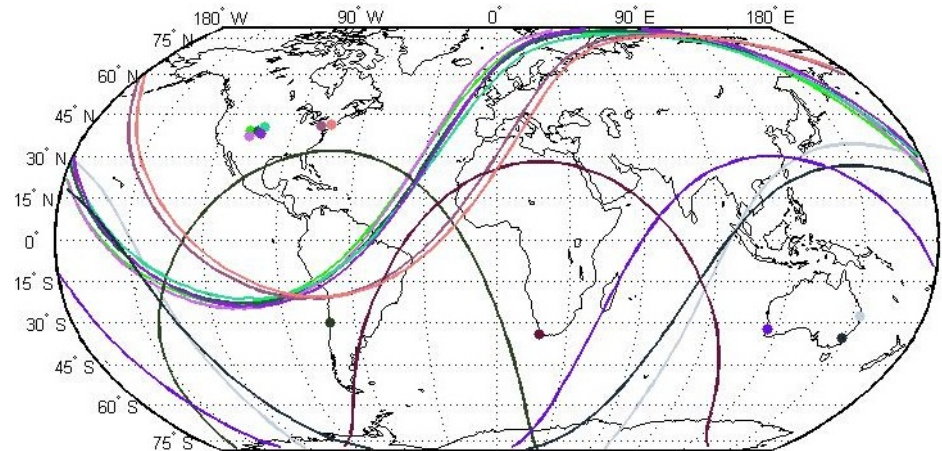


FTN: Global Coverage

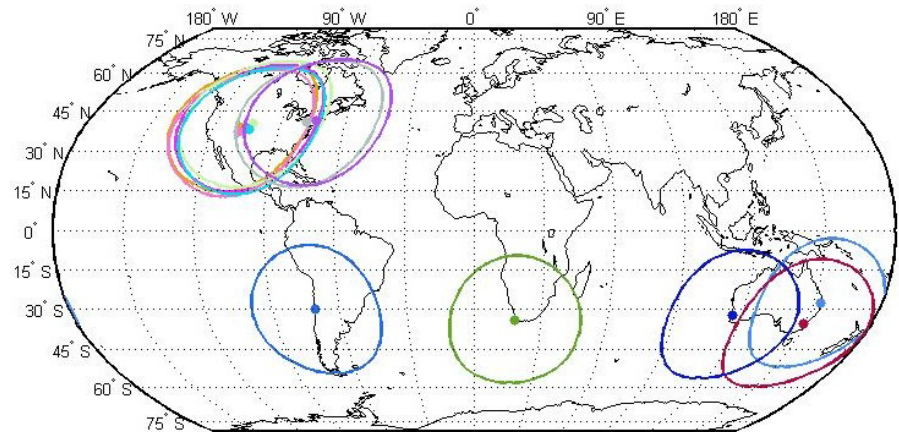


Partners

- **U.S**
 - Colorado Mesa University (Grand Junction)
 - Fort Lewis College (Durango)
 - Northeastern Junior College (Sterling)
 - Otero Junior College (La Junta)
 - Penn State University (State College)
- **Chile**
 - Universidad de La Serena (La Serena) & Observatorio Mamalluca (Vicuña)
- **Australia**
 - University of Queensland (Brisbane)
 - Curtin University (Perth)
 - University of New South Wales & EOS (Canberra)
- **Potential:** South Africa, Kauai Community College, International Space University



Global Coverage (GEO)



Global Coverage, (LEO, 1000 km)



Molecular Physics

Periodic Nuclear Decay Rates



The Mystery of Periodic Nuclear Decay Rates

- Familiar exponential decay law:

$$\dot{N}(t) \equiv \frac{dN}{dt} = -\lambda N_0 e^{-\lambda t}$$

- Periodic Variations Reported in 25 Long-term Nuclear Decay Experiments

- Select β & E.C. Decay Affected
- Wide variety of detectors types
- Few experiments run for many years; independent confirmation difficult

Raises the possibility that either the detectors or the decays in question are being affected in some fashion by an external influence such as seasonal variations or solar radiation.

Regardless of causality, understanding nature of periodicities offers crucial insight into long-term detector operations supporting scientific, national defense, and industrial applications.



Isotope	Effect Observed
^3H	Periodicity: 1 yr ⁻¹
^3H	Periodicity: 1/d, 12.1 yr ⁻¹ , 1 yr ⁻¹
^3H	Periodicity: ~12.5 yr ⁻¹
^3H	Periodicity: ~2 yr ⁻¹
$^{22}\text{Na}/^{44}\text{Ti}^{[a]}$	Periodicity: 1 yr ⁻¹
^{36}Cl	Periodicity: 1 yr ⁻¹ , 11.7 yr ⁻¹ , 2.1 yr ⁻¹
^{36}Cl	Periodicity: 1 yr ⁻¹
^{54}Mn	Periodicity: 1 yr ⁻¹
^{56}Mn	Periodicity: 1 yr ⁻¹
^{60}Co	Periodicity: 1 yr ⁻¹
^{60}Co	Periodicity: 1/d, 12.1 yr ⁻¹
^{85}Kr	Periodicity: 1 yr ⁻¹
$^{90}\text{Sr}/^{90}\text{Y}$	Periodicity: 1 yr ⁻¹ , 11.7 yr ⁻¹
^{108m}Ag	Periodicity: 1 yr ⁻¹
^{133}Ba	Periodicity: 1 yr ⁻¹
^{137}Cs	Periodicity: 1 yr ⁻¹
^{152}Eu	Periodicity: 1 yr ⁻¹
^{152}Eu	Periodicity: 1 yr ⁻¹
^{154}Eu	Periodicity: 1 yr ⁻¹
$^{222}\text{Rn}^{[c]}$	Periodicity: 1 yr ⁻¹ , 11.7 yr ⁻¹ , 2.1 yr ⁻¹
$^{226}\text{Ra}^{[c]}$	Periodicity: 1 yr ⁻¹ , 11.7 yr ⁻¹ , 2.1 yr ⁻¹
^{239}Pu	Periodicity: 1/d, 13.5 yr ⁻¹ , 1 yr ⁻¹

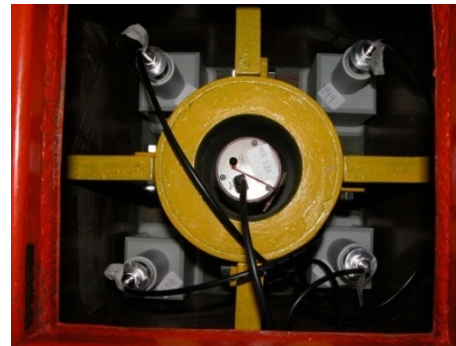


CCHEN Decay Experiment: Present Status



Detector Network of 4 Sites

- Chilean Commission of Nuclear Energy (CCHEN)
- USAFA
- Purdue University
- Brigham Young University
- **Mimic IMS Measurements but at Higher Data Rates & longer Integration Times**
- **Variety of Detectors, Sources**
 - Empty Detectors as Control
 - Monitor Environ. Variables
 - Custom, Full Lead Shielding
- **CCHEN detectors set up & calibrated in Sept 2012**
 - Data looks good, but too soon to evaluate significance
 - Expect 2 yr runtime, first results in 9 months



View of Test Chambers (top), Gieger Mueller and NaI Detectors with ^{54}Mn , ^{32}Si , ^{36}Cl , ^{90}Sr , and empty NaI detector



Material Science and the Mexican Initiative

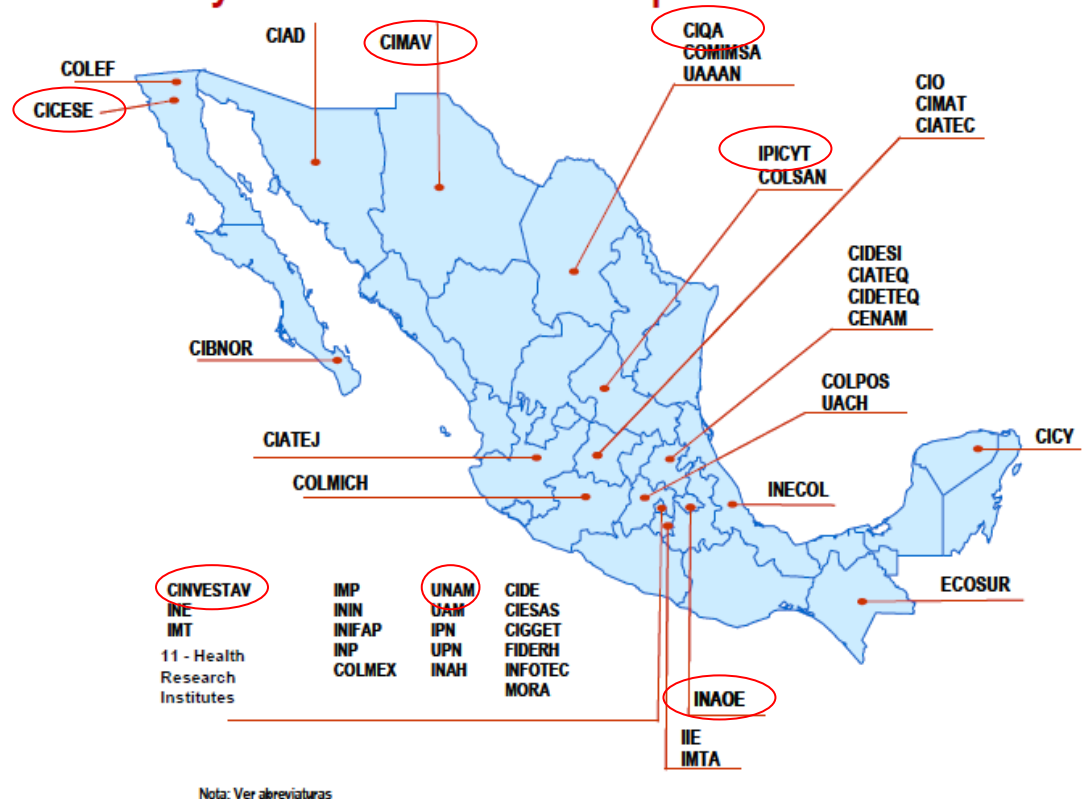


Exact & Natural Sciences

CIAD	Food products and processes, social and economic development related to food products and processes
CIBNOR	Sustainable management of natural resources
CICESE	Biological sciences, physics, information technology, marine and geological
CICY	Biological vegetation, natural resources and materials science
CIMAT	Mathematics, probabilities, statistics and computational sciences
CIMAV	Nanotechnology, materials, environment and energy
CIO	Optics
INECOL	Ecology, biodiversity and natural resources management
INAOE	Astrophysics, optics, electronics and computational sciences
IPICYT	Molecular biology, biotechnology, geosciences, advanced materials, nanotechnology, environmental sciences and applied mathematics
CIQA	Polymer synthesis, polymerization processes, plastics transformation, advanced materials, and agricultural plastics

CONACYT Research Centers

Primary Research and Development Centers in Mexico.



National Labs work with universities, but, only receive graduate students.
Major funding support by CONACYT



AFOSR – CONACYT Joint Projects



AFOSR – CIMAV – CONACYT “U.S. / México – Basic Research Initiative”

BASIC RESEARCH PROJECTS:



CONACYT

Project 1: “Modeling, Development and Characterization of Alternate Electrodes for Flexible Electronics Applications.”



The University of Texas
at Dallas:

• Dr. Bruce Gnade, Ph.D.

CIMAV - Unidad Monterrey

• Dr. Francisco Servando Aguirre-Tostado



Project 2: “Multi-Phase, Multifunctional Ceramic Coatings.”

The University of California
at Santa Barbara:

• Dr. Carlos Levi, Ph.D.

CINVESTAV – Unidad Querétaro:

• Dr. Gerardo Trápaga-Martínez



Project 3: “Hybrid Solid-State Photovoltaic Materials and Devices.”

The University of Akron:

• Dr. Matthew Espe, Ph.D.

CIQA – Saltillo:

• Dr. Ronald F. Ziolo



Project 4: “Laser-induced patterning of transparent ceramics and metallic films for photonic and sensing applications”

The University of California
at Riverside:

• Dr. Guillermo Aguilar, Ph.D.

CICESE – Ensenada:

• Dr. Santiago Camacho-López



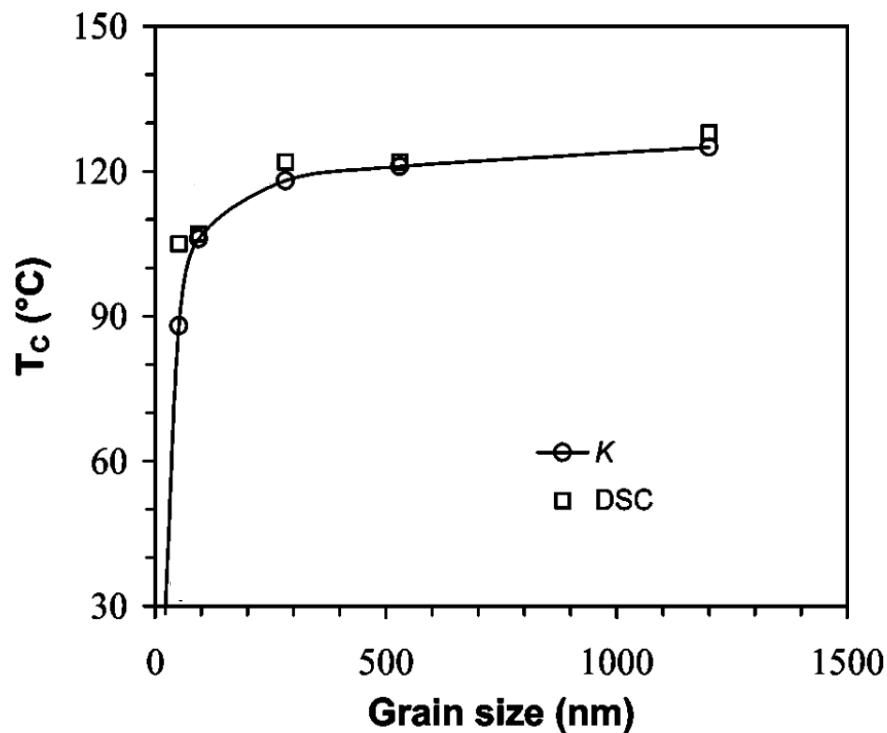
Final Program Review tentatively scheduled Aug - Sept 2013 in Mexico



Success story: Development of Ferroelectric Nanoparticles



Collaborators: AFRL/RXPJ, AFOSR
CIQA, Mexico



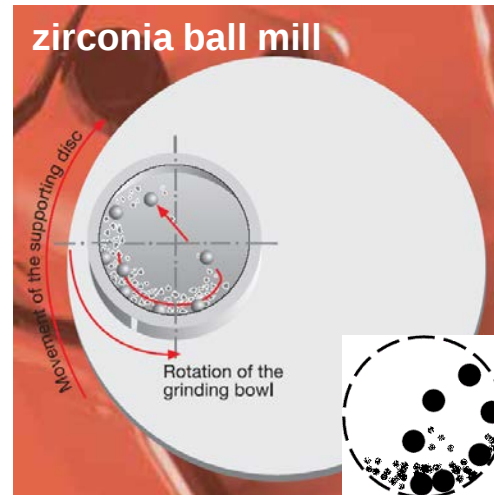
Critical temperatures of BaTiO₃ ceramics as a function of grain size.

Barium titanate, BaTiO₃, is a white powder and transparent as larger crystals. It is a ferroelectric ceramic material, with a photorefractive effect and piezoelectric properties.

- **General belief by researchers -**
Typical BaTiO₃ loses its ferroelectricity at sizes smaller than 30-50 nm
- Size restrictions limited number of potential applications



Mechanically Induced Surface Stress



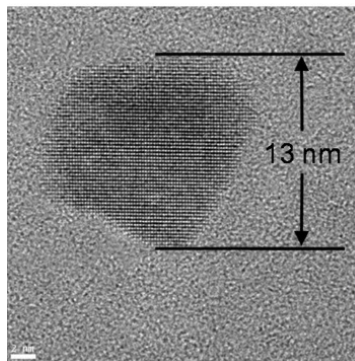
Particle sizes limited to:

- ~1 μm with simple solvents
- 9 nm with surfactant

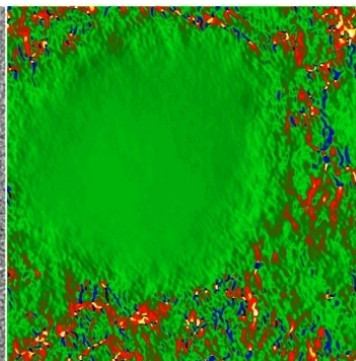
Bottom up – synthesizes particles from atoms and molecules

Top down – particles are reduced to nanometer size by grinding

HRTEM image



Strain Map



- AFRL/RXPJ developed the world's smallest ferroelectric nanoparticle, as small as 9 nm.
- Surface stress believed key to this achievement
- Through collaboration with CIQA, a strain map was made on RXPJ's nanoparticles, proving the hypothesis that surface stress was present.²¹



Examples of Systems with Disparate Nanoparticle Roles



- Photorefractive beam coupling: electric torque
- Liquid crystal display: DC bias
- Metatronics (Metananocircuits)
- Massive Dipole Field Effects

Results with 9 nm-harvested stressed
ferroelectric nanoparticles



Extremophile Research



- **Collaborators: AFOSR & BioScience Foundation, Chile.**
 - Studies started with isolation of novel heat resistant micro-organism from laboratory drying ovens: **E1** and **E2**. (2007)
 - **One unexpected result:** Biosynthesis of Selenium (Se) nanoparticles by E1

Identification of microorganisms



Se NANOPARTICLES BIOSYNTHESIS



E1



Extremophile - Accomplishments

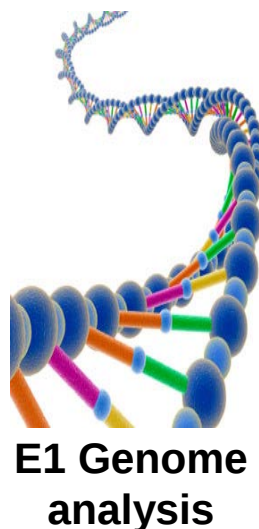
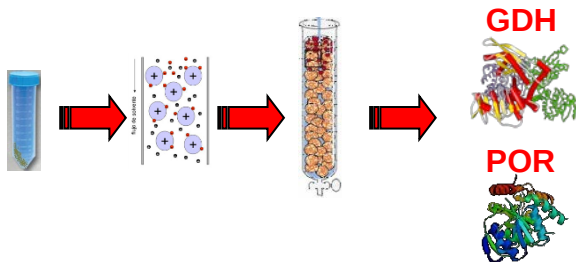
Bioscience Foundation, Chile



Project Accomplishment

- Isolation of novel heat resistant microorganism: E1 and E2.
- Desiccation resistance for the microorganisms
- Isolation and characterization of enzymes: GDH and PDH or POR.
- Lipids Profiles and analysis. Studies of DNA repair mechanisms.
- Contribution of the antioxidant enzymes to the resistance to extreme and fluctuating UV radiation.
- Cloning and expression into *Escherichia coli* of genes

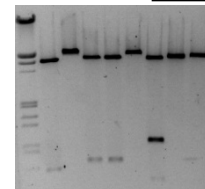
Characterization of enzymes GDH and POR



Catalase
(CAT)

Superoxide
dismutase
(SOD)

Specific
Primers
design



Expression of genes
in *E.coli*



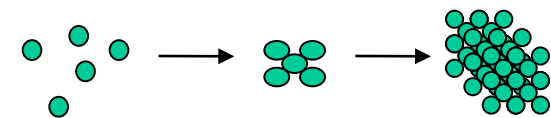
Extremophile – Future Goals *Bioscience Foundation, Chile*



Research Goals to be accomplished

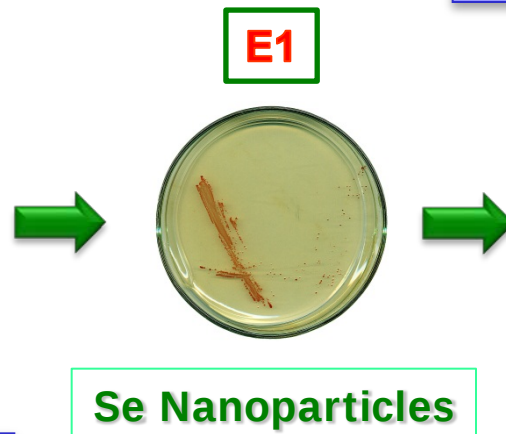
- To study the role of enzymes in the biosynthesis of Se nanoparticles.
- To study the effect of temperature, pH and salt concentrations in Se nanoparticle size and shape.
- To demonstrate that this is an enzyme-mediated process.

Nanocrystals biosynthesis

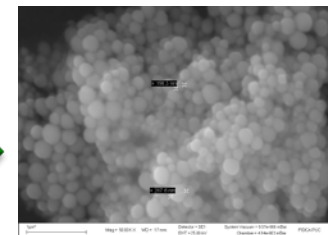
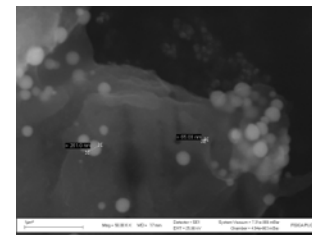
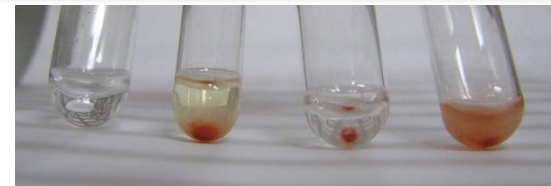


1. Local supersaturation
2. Nucleation
3. Growth

Complex phenomenon,
not well studied



Influence of enzymes on selenium nanoparticles synthesis



Se Nanoparticles biosynthesis

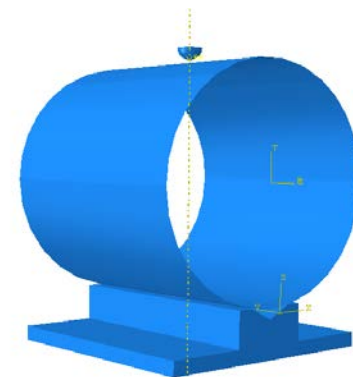
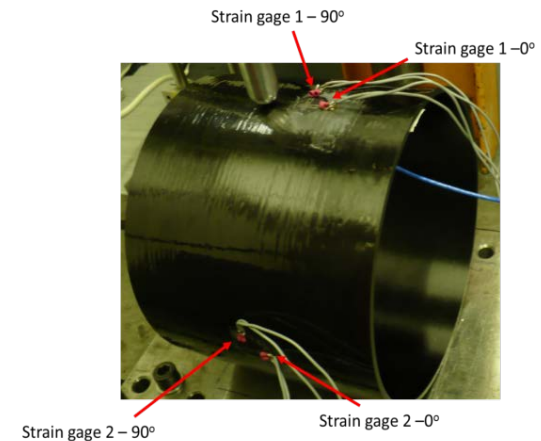


Structural Mechanics

Filament Wound Structures



- **Project:** Damage and Progressive Failure of Filament Wound Structures
 - Collaborators, Army ARDEC, AFOSR, and ta, Univ of Sao Paulo
- **Objective:** Investigate new mathematical formulation for damage models used in aviation filament wound structures
 - High precision, low computational cost
- **Necessary for:** structural integrity, health monitoring, and service life assessment





Structural Mechanics

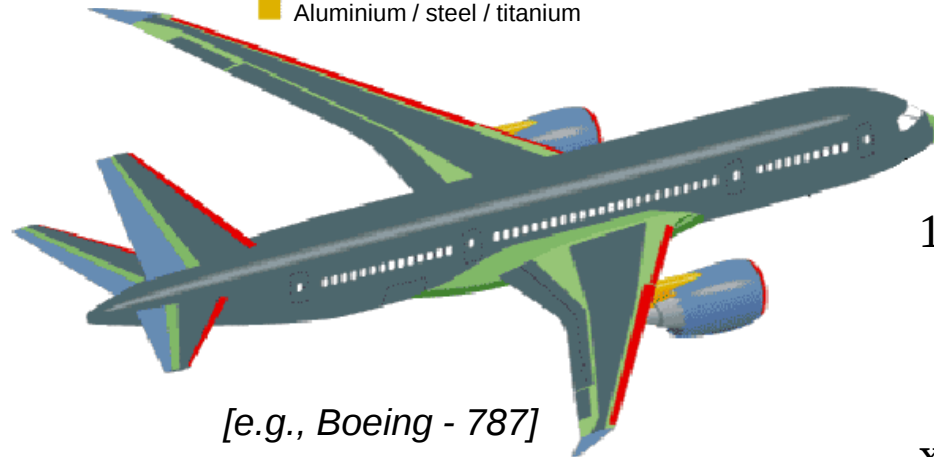
Filament Wound Structures



Motivation

High Specific Properties

- Glass fiber
- Aluminium
- Carbon composite laminates
- Carbon sandwich composites
- Aluminium / steel / titanium



[e.g., Boeing - 787]

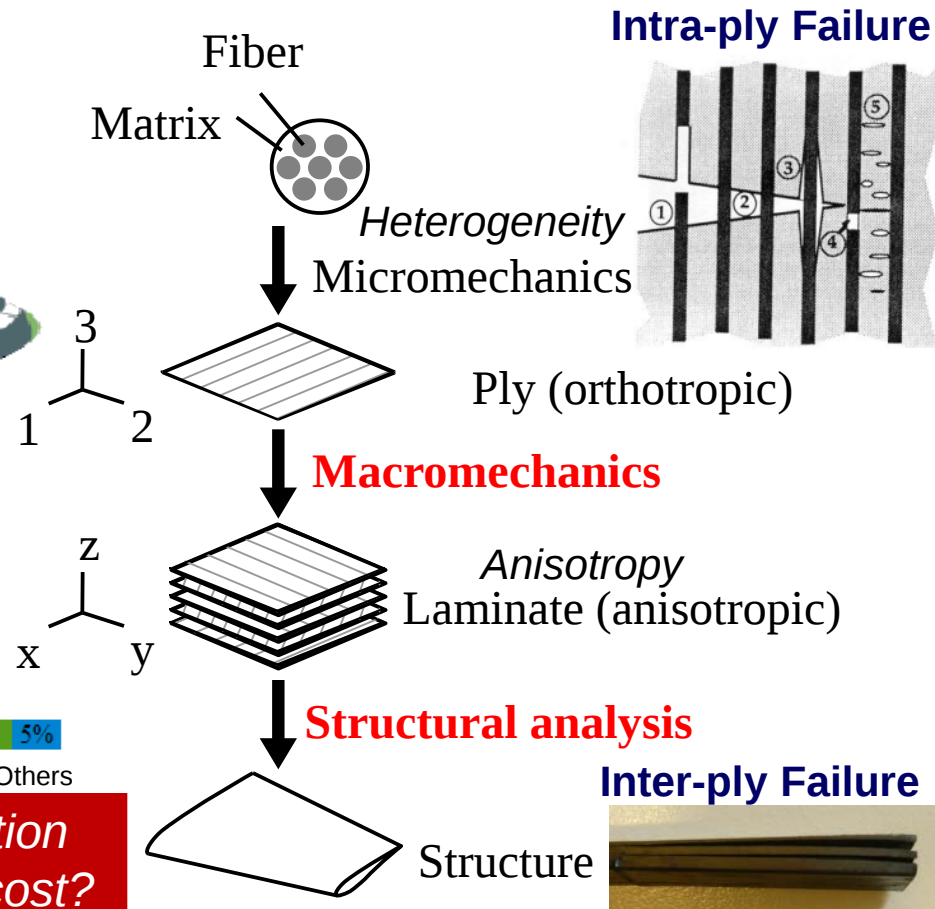
Materials used by weight



How to calculate stress and strain distribution with high accuracy and low computational cost?

How to predict damage/failure modes and loads with high precision and low computational cost?

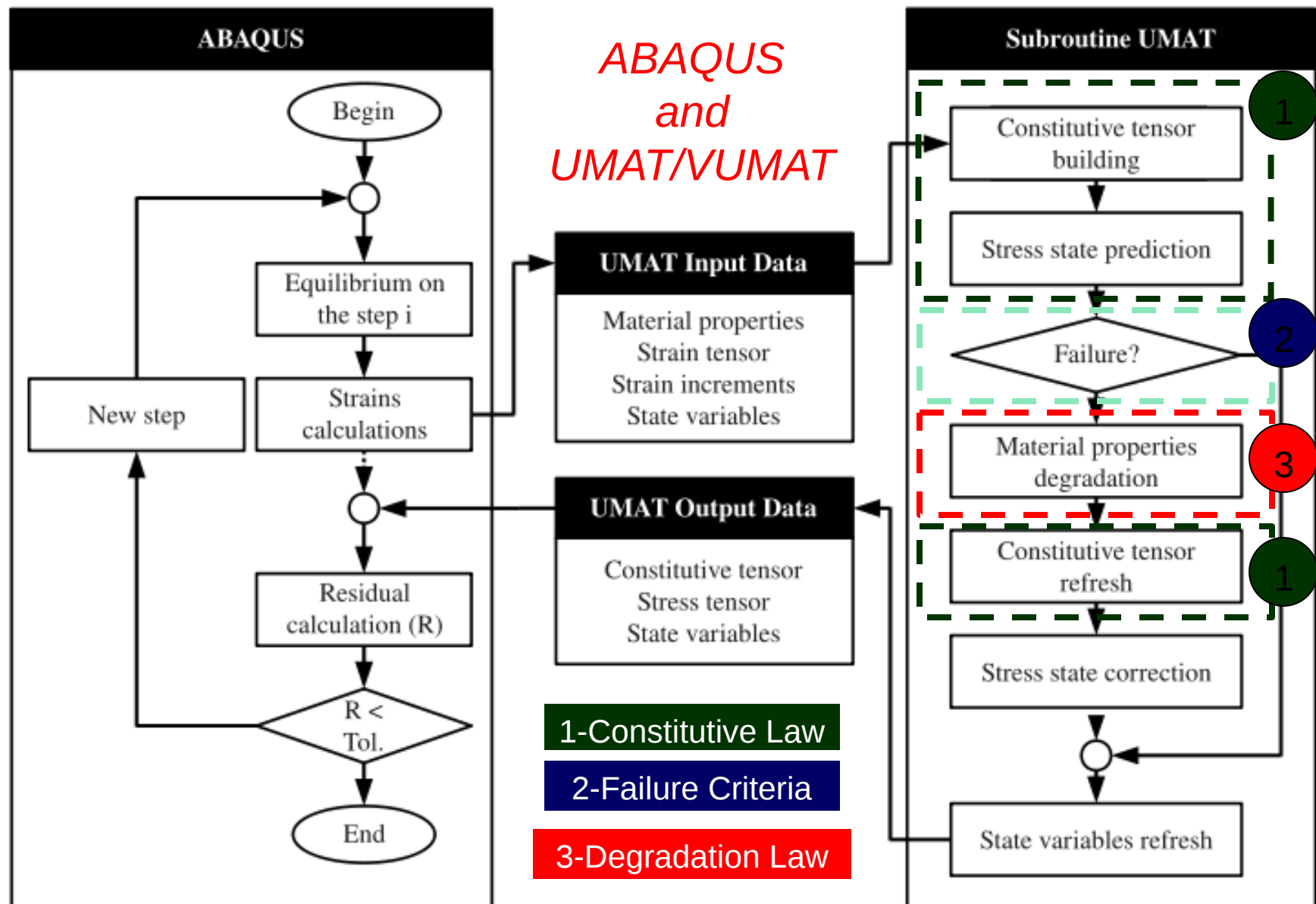
Challenges





Damage Model Implementation

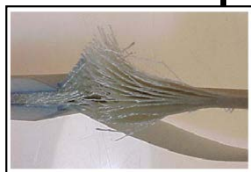
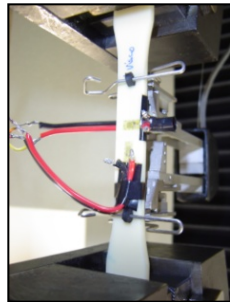
Filament Wound Structures





Damage Model Validation

Filament Wound Structures

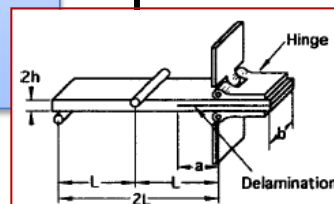


Experimental tests

- Tensile
- Compression
- Shear
- Bending
- Mode I
- Mode II
- Mix Mode
- Hopkinson's bar

- 4 point Bending
- Indentation on plane and curved specimens
- Impact on plane and curved specimens

Model parameters



Model evaluation

Computational model

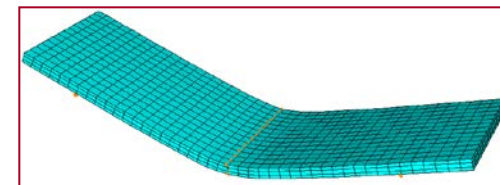
Abaqus

Abaqus implicit subroutines for plane and curved geometry

- ❖UEL
- ❖UMAT

Abaqus explicit subroutines for plane and curved geometry

- ❖VUEL
- ❖VUMAT



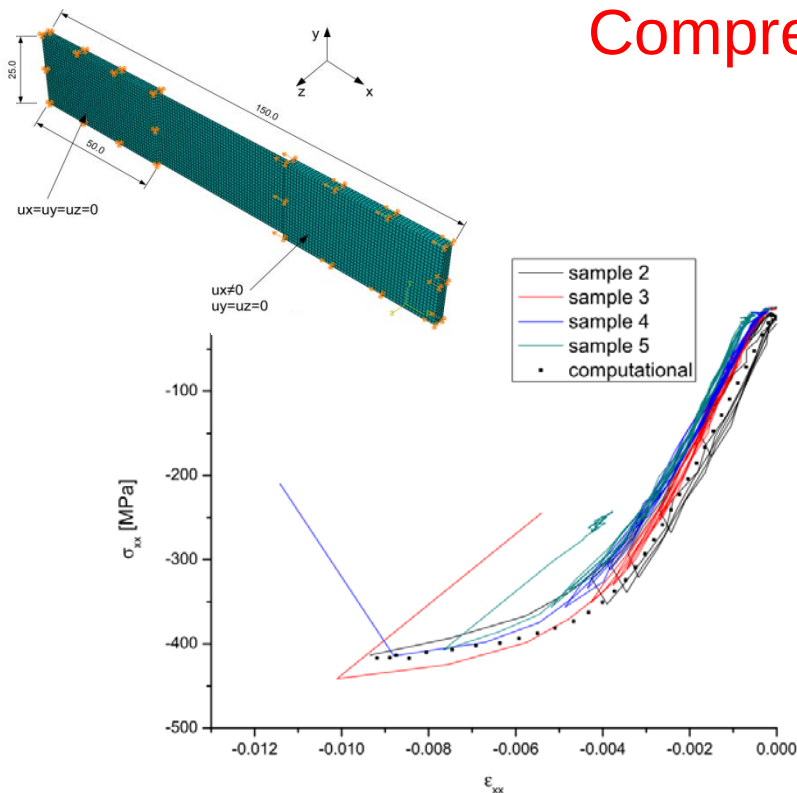


Example of Validation Test Results *Filament Wound Structures*

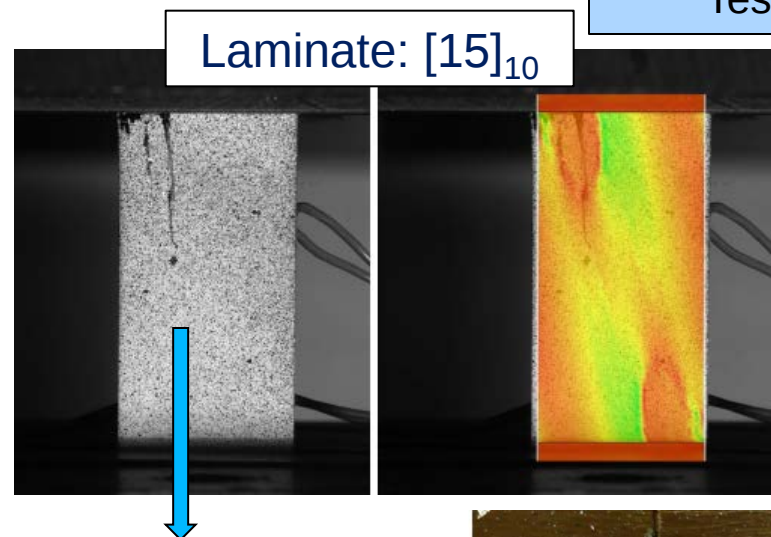


Compression Analyses

Uniaxial
Compression
Tests



Maximum Failure Stress
~ 450 MPa

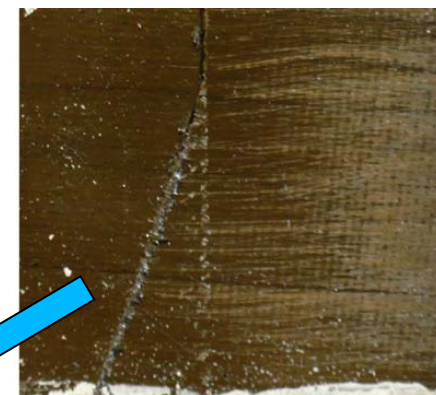


Matrix Failure

Non-linear behavior

Local phenomena

Micro-buckling and
kinking of fibers





Aerodynamics

Stability of Coaxial Free Jet Flow



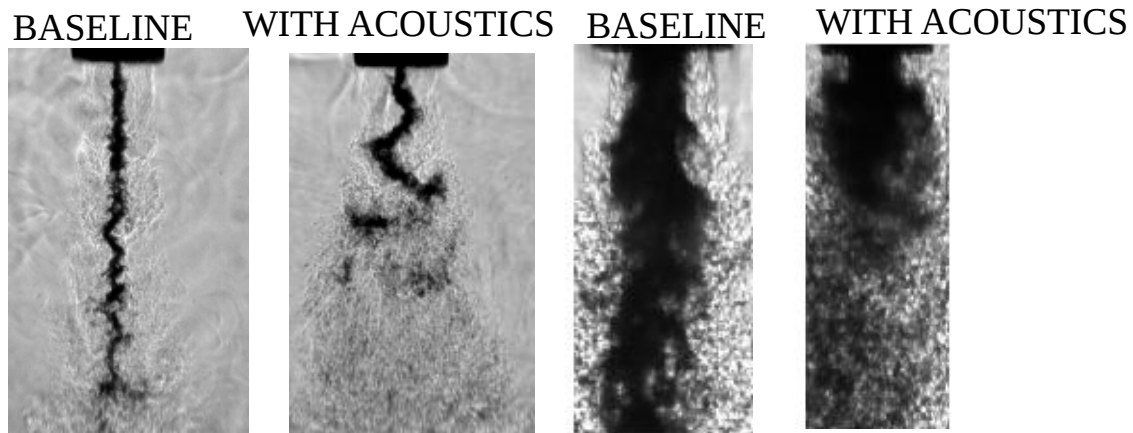
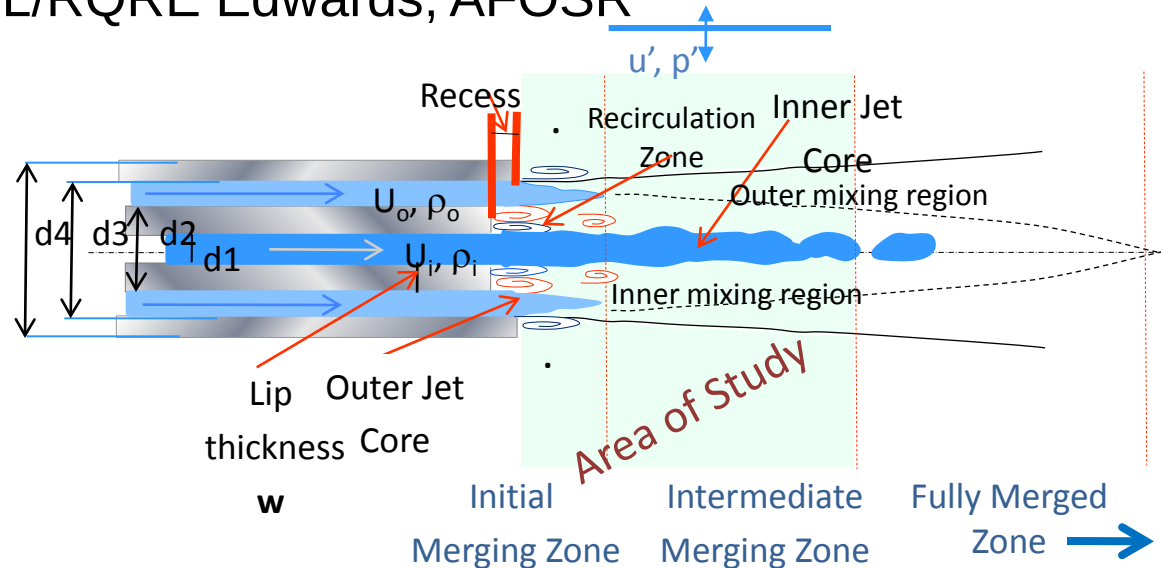
Collaborators: Fluminense Federal University, Brazil
AFRL/RQRE Edwards, AFOSR

Objective: Perform a stability analysis for coaxial jets to better understand the natural hydrodynamic instabilities of this canonical geometry for liquid rocket engines

- Baseflow will be established
- The outer jet and the inner jet wall thickness will be incorporated into analysis

Benefits:

- Better understanding of the natural instability modes of this class of injectors and how the wall thickness affects the hydrodynamics



Examples of coaxial base and acoustic driven flows



Concluding Remarks

State of Latin American Research



- **Latin American research is growing fast and becoming more visible on the global scale.**
 - **Between 2000 and 2010***
 - Growth of more than 9% per year in scholarly output
 - 70% increase in its share of world papers and citations
- **SOARD Project Officers will continue to cover a broad range of topics in BAA seeking the best scientists of Latin America.**
 - Space portfolio will remain a key area to take advantage of unique resources space research worldwide)
 - Group formed in AFOSR to coordinate space research worldwide.

* Research Trends Issue 31 November 2012