The Kennedy Space Center Applied Physics Lab

October 23, 2014

Robert C. Youngquist

2014 South East Regional Space Grant Fall Meeting

The Early Years, 1989-1999

During the return-to-flight period after Challenger (1986-1988), KSC ramped up its technical personnel.

Many engineers and technical specialists were hired to support and upgrade Shuttle processing. I and the original lab team were brought together at this time and told to go be productive.

Money was available, but “cultural” issues raised roadblocks to introducing new technology.

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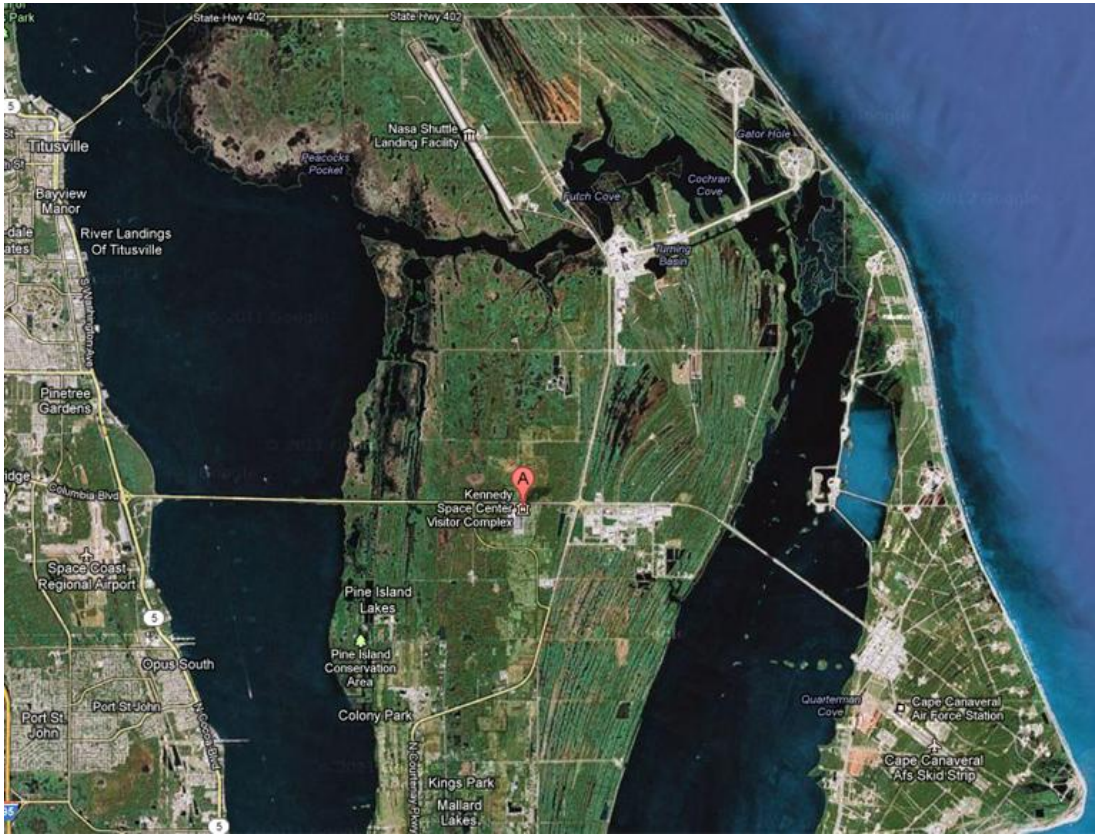
The Shuttle community was resistant to change because change could be potentially dangerous.

The engineering community was committed to improvement, which implies change. But you can't force change when it isn't wanted.



Geographically, the industrial or engineering area was separated from operations by several miles.

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I was directed to go to operations and simply ask, “what do you want?” and a rapport was established.

Our first products were used to help position the External Tank during its attachment and alignment with the Solid Rocket Boosters.

One of our primary accomplishments was getting approval to put low power lasers into the field.

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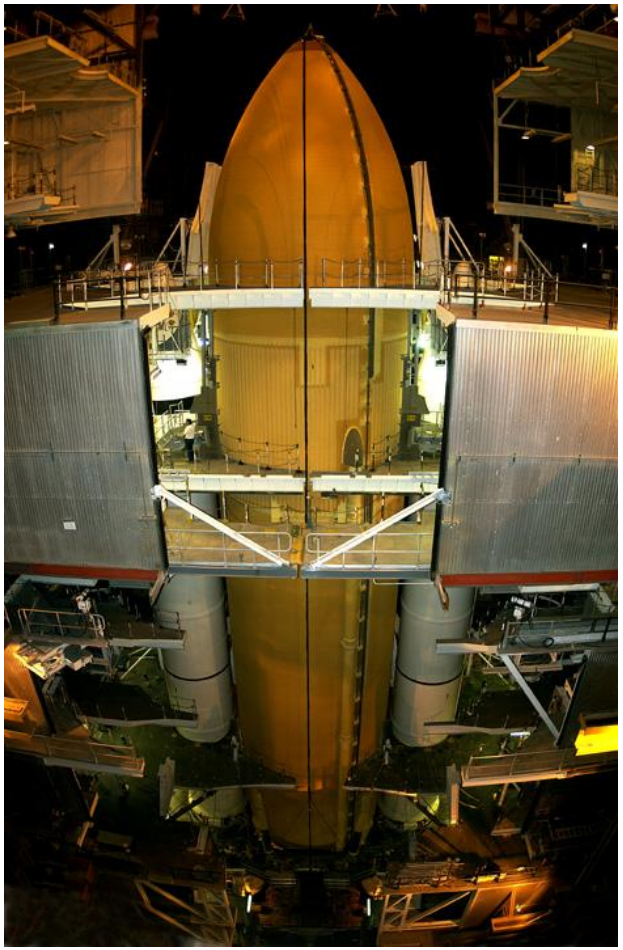

We developed a laser based device to help position the External Tank during crane operations and during demate operations.

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The External Tank Centering and Alignment system provided real-time measurements on the gap between the SRBs and the ET, allowing the aft end of the ET to be centered.

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Here is a device we developed to align the GOX Vent Hood over the ET at the Pad, again using lasers and ultrasonic ranging.

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When laser rangefinders became available we used them to construct a system to provide real-time monitoring of the height of the four corners of the Orbiter to allow accurate positioning within the Orbiter Processing Facility.

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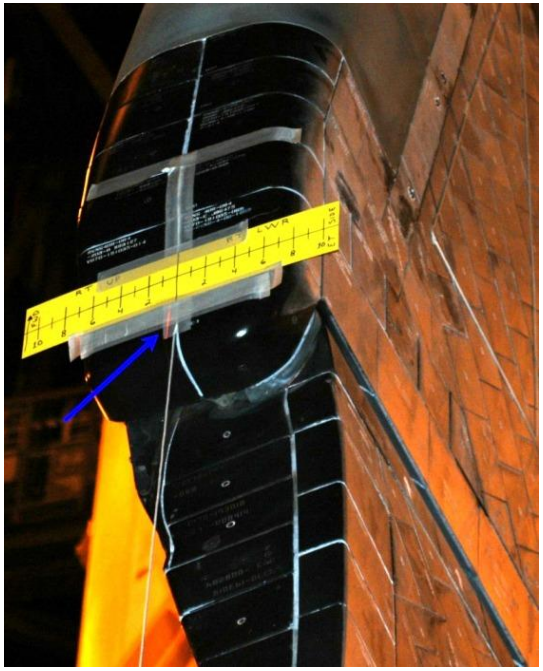
During Orbiter crane operations it is necessary to align the wing tips with survey marks prior to lowering it into the integration cell.

We developed a laser line projection system to allow this positioning to be performed.



AIAA Space 2011
Success Legacy of the Space Shuttle Program

The lab's success in developing positioning and laser based tools, led to more customers and a broadening of requests.

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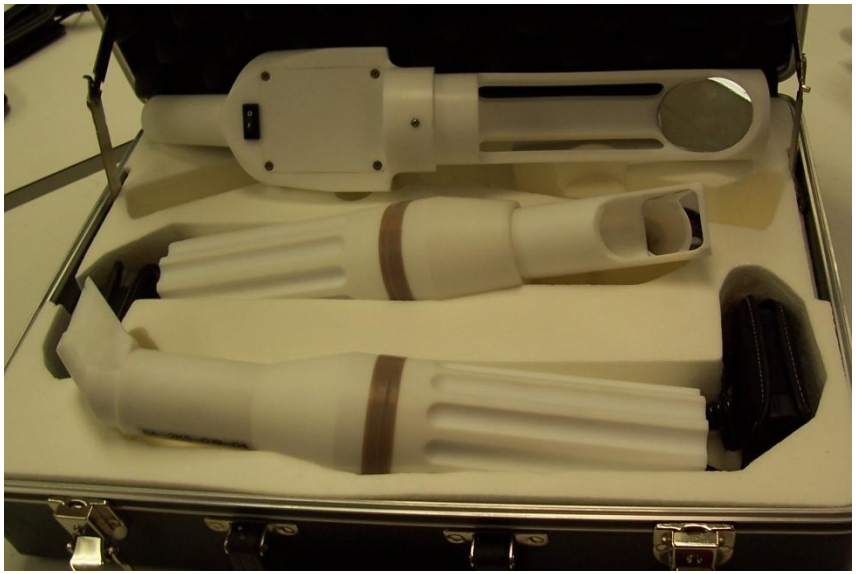
We developed a set of Teflon/plastic-optic inspection tools for the reaction control system rocket nozzles. These allow the hypergol openings, the chamber lining, and the acoustic holes to be inspected.



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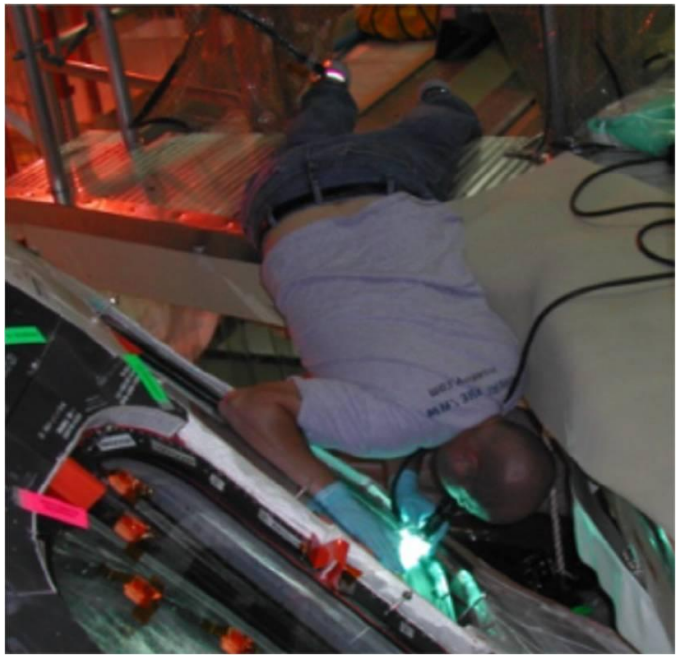

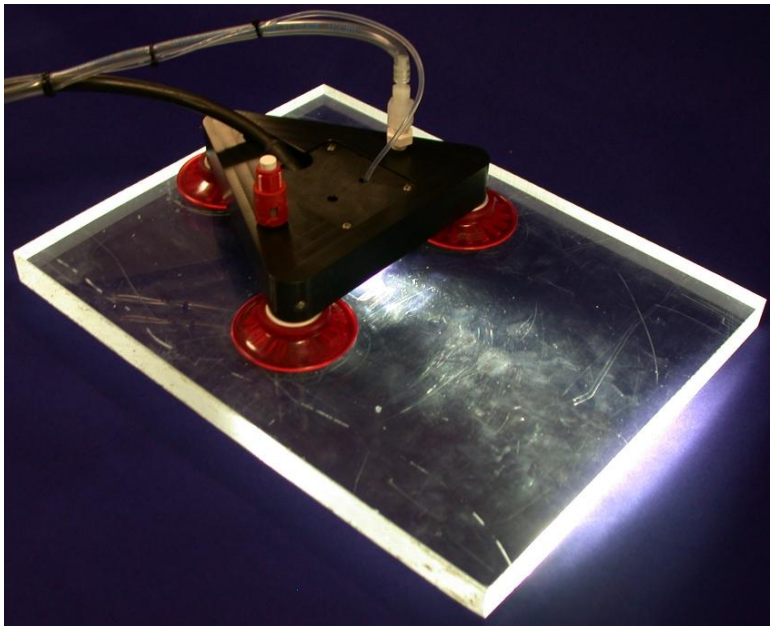

We then became involved with inspecting the Orbiter windows for defects. We developed a highly used tool that couples light into the window panes, causing defects to light up and become visually apparent.

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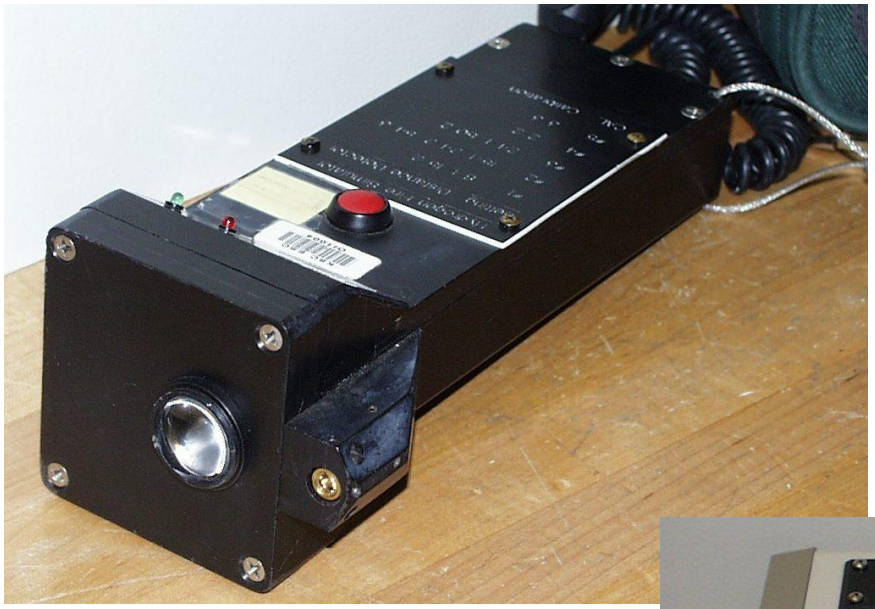

We developed and patented a UV hydrogen fire simulator (used to certify the Pad fire detection system) and a fire detector calibration system.

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We extended the state-of-the-art in ultrasonic leak detection. This work started as a way to help detect hydrogen leaks in the Orbiter aft, but advanced into a general purpose leak detection tool.

Our advances were patented (early 1990s). A commercial version was developed and is still being sold today.

The Golden Years, 2000-2004

During this period the Shuttle Ground Processing Program formed a path whereby problems were directed through a front office and then to us. We were well funded and either handled these problems or passed them out to other labs.

During the late 90's KSC was developing more new technology (tech briefs) than the research centers. Technology development was encouraged and new labs were forming.

We expected the Shuttle program to run another 20 years, but then the Columbia disaster occurred in early 2003. The ramifications took a year to reach us.

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We developed a system that can vacuum water out of the Shuttle tiles by attaching a small suction cup to the water-proofing opening in a tile.

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We've developed two different water detection instruments. One pulls a sample of air from a cavity (e.g. a tile) to determine if water is present and the other measures capacitance (like a stud finder) .

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Hail storms occur about once a year at the pad and the size and severity of the storm can determine the need for repair. We developed a hail sensor that measures the size of the hail stones that hit it.

A few more items we worked on during this period include:

1. Color changing hydrogen detection tape (this won an R&D-100 in 2014).
2. A remote scaling device for sizing defects on the ET (patented and commercialized).
3. Crane positioning tools,
4. Inspection tools,
5. Over-center measurement device,
6. An enhanced window defect detection device,
7. An ET hydrogen leak detection sensor.

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The Shuttle Decline, 2005-2011

After Columbia Shuttle missions were limited and then end of the program eventually announced. We lost our flexible funding and now only projects that carried their own funding could be worked and as the end approached those became difficult to find. Who would want to fund an upgrade for a program that was ending?

During this period half of the lab migrated over to work on a lunar water processing factory (RESOLVE). Hopefully this will be KSC's first piece of lunar hardware.

Let's discuss one odd problem in more detail…

Movie of Orbiter hitting a vulture while taking off at a Launch Pad.

July 2005 launch of Discovery on mission STS-114

So how do you get rid of the vultures?

Turkey Vulture

Can't shoot them.

Chemical deterrents only keep them off the ground.

Hanging up fake dead vultures keeps them off the pad, but not out of the airspace.

Black Vulture

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How one NASA center solved their vulture problem.

When we tried this we captured a gator instead of vultures.

LRAD-Long Range Acoustic Device

Driving the vultures away with loud sounds works, but the program decided it was too expensive to implement.

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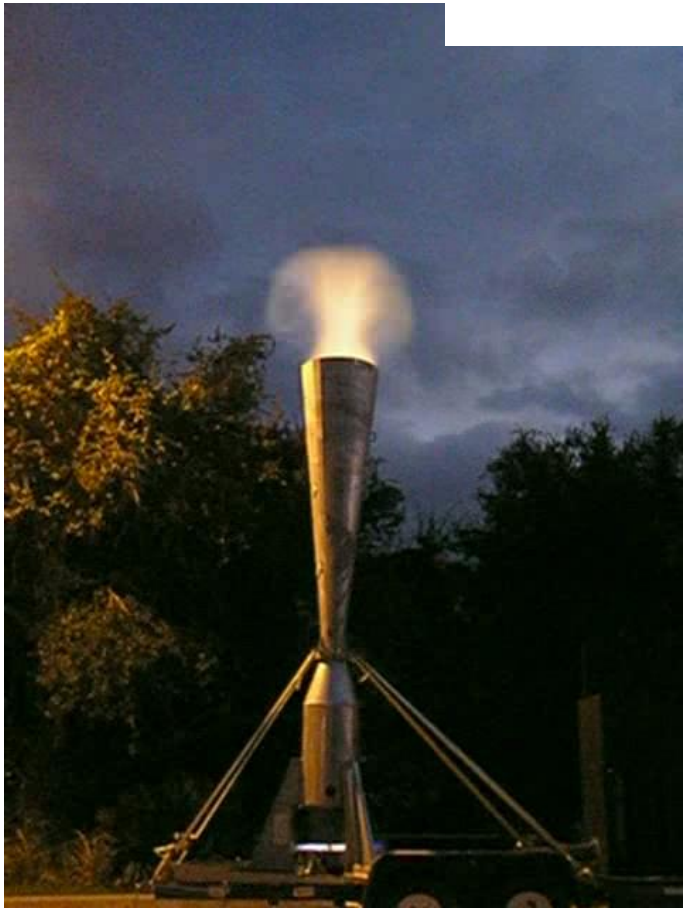

Someone suggested we use a cannon and this works. After a series of blasts the vultures clear the area.

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I spent time at the pad measuring the blast wave pressure to determine if there might be an impact to the Shuttle, but the program decided not to implement the cannon.

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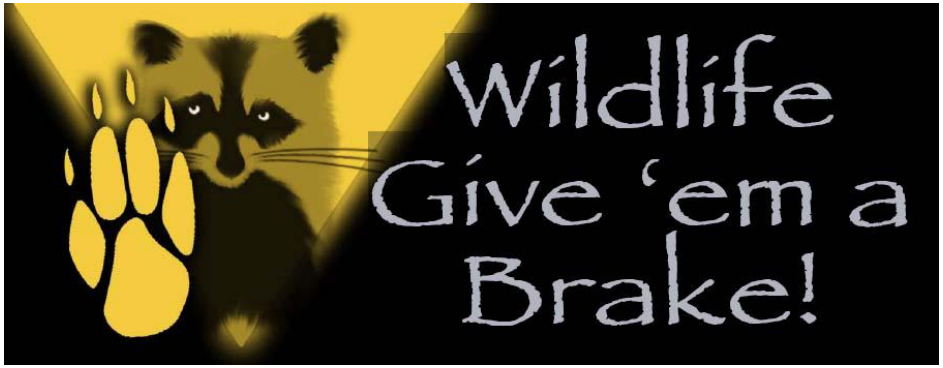
Instead, they began collecting road-kill to cut back on the food supply and started a campaign to try and reduce road-kill.

In addition they asked us to develop a vulture tracking system for use at launch.



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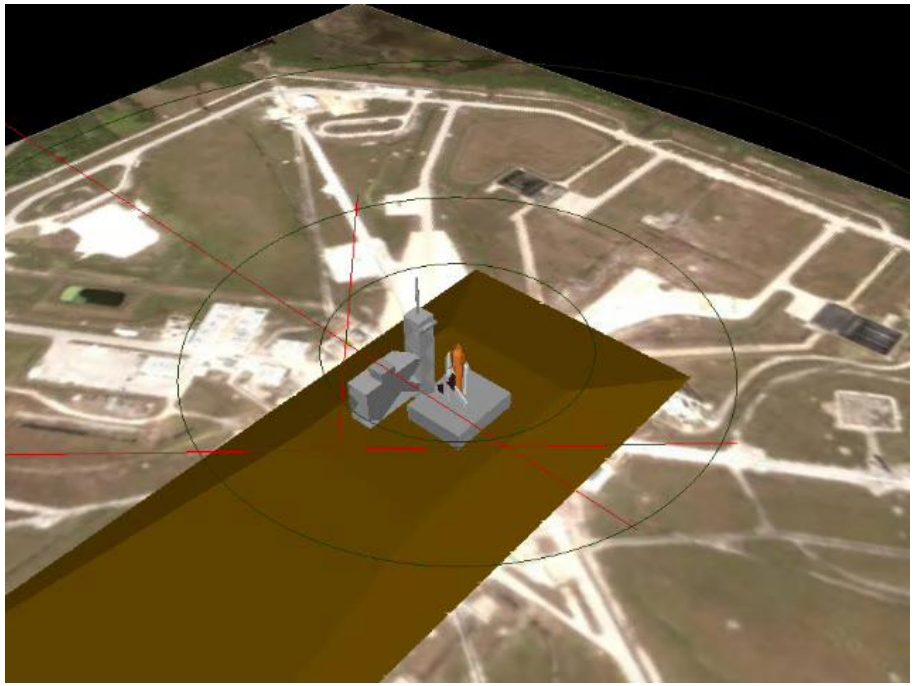

We “borrow” 3 cameras prior to each launch and use them to triangulate the location of any vultures located over the pad. A 3-D model of the pad with bird locations is displayed to the launch director

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H2 Flame

Water tower

This is the view from the three cameras used to support the bird vision system.

Note the image on the left. This is the only visible image I know of showing the flare stack burning at take off.

Also, note the water tower….

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The water deluge system being tested.

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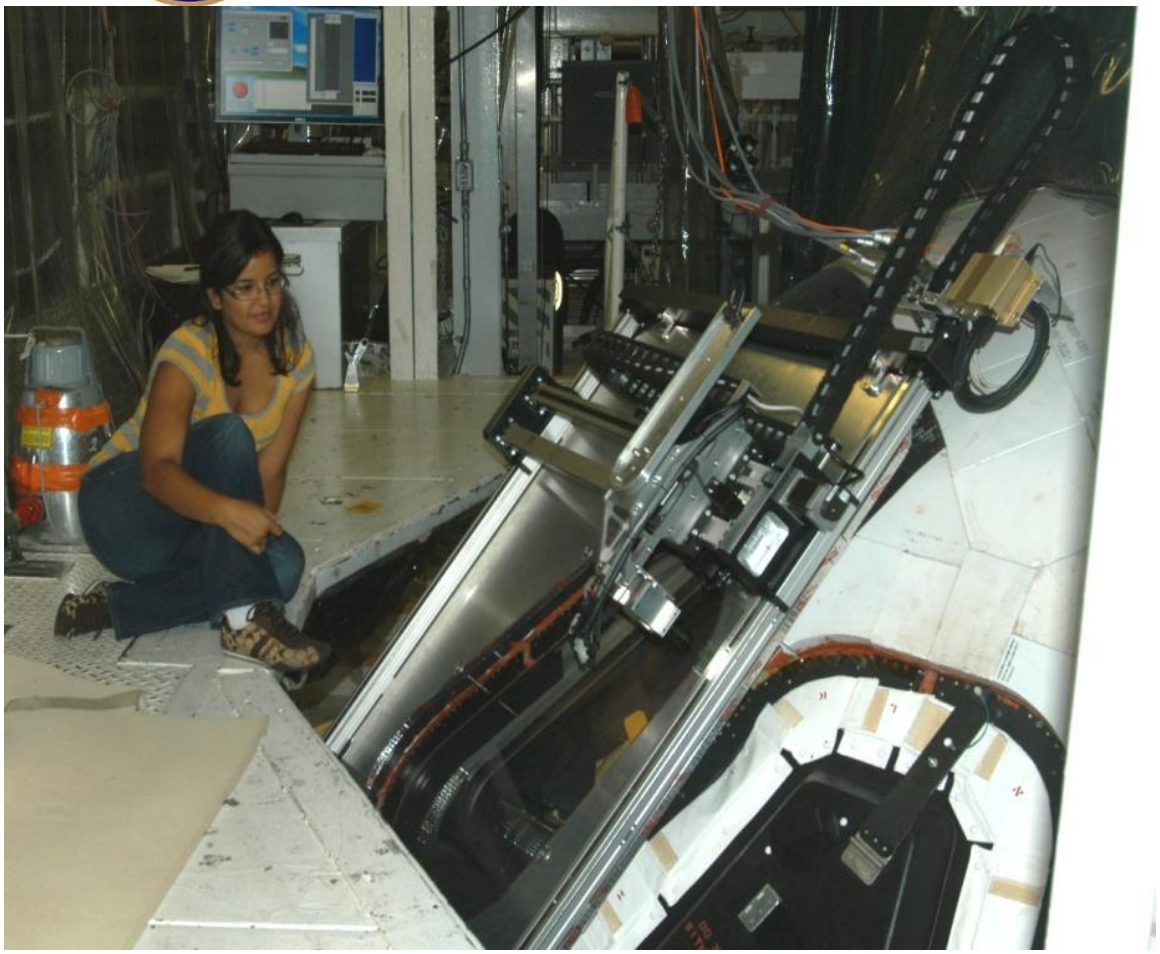
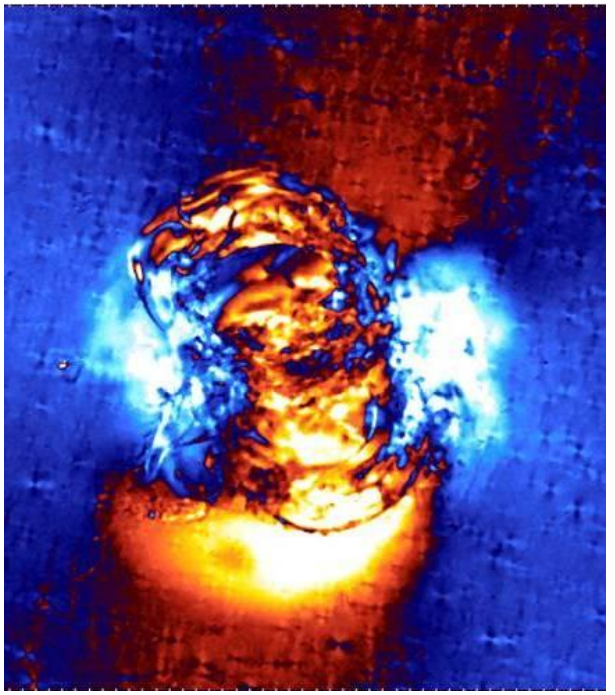
Now back to the main story…





A stress image of a window defect.

We developed a window scanner that could be attached to the Orbiter and used to map defects, producing actual images of the stress fields associated with the defect.

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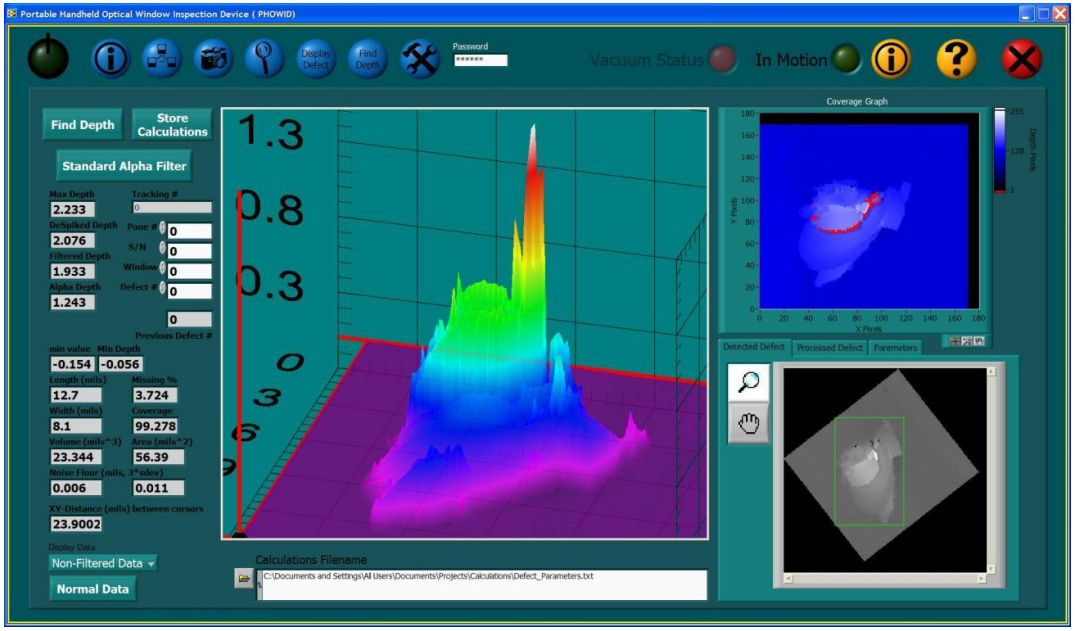

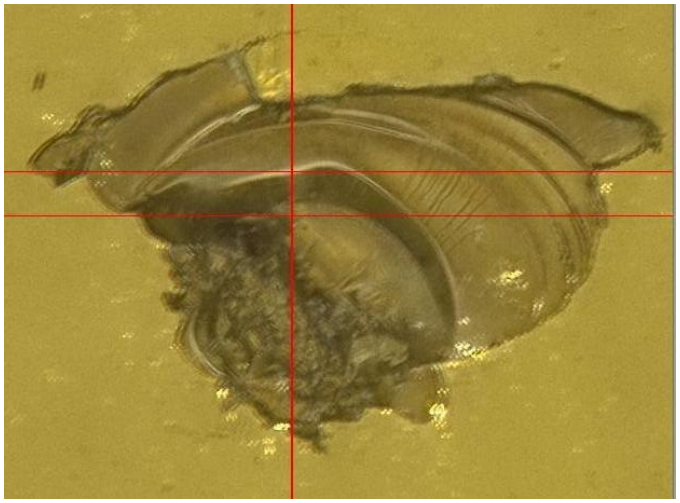

We developed a portable tool that could be attached using suction cups to the Orbiter windows and used to measure the surface topography of a defect to 1 micron height resolution.

AIAA Space 2011
Success Legacy of the Space Shuttle Program

Desiccant canisters are used to clean and dry the air sent to the Orbiter window cavities. We developed a system allowing the flow through these canisters to be monitored in place, without removing them from the Orbiter.

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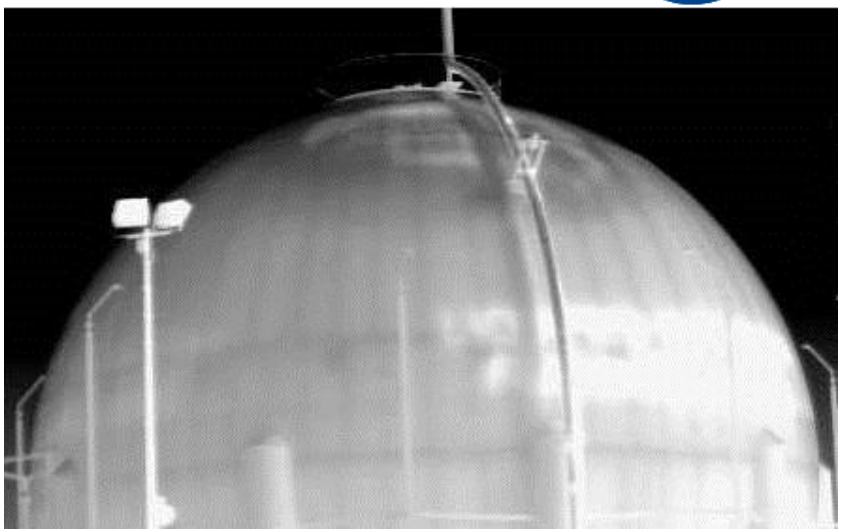

The Pad B liquid hydrogen tank had a large heat leak. We became involved and helped to show, through modeling and IR imagery, that the tank was missing insulation, but that it appeared to be structurally sound.

When the tank was later emptied and opened for inspection our analysis was confirmed.

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Research and Technology, 2012-2014

The Shuttle program ended in 2011.

Half of Applied Physics Lab lab is still working on a lunar water processing factory (RESOLVE).

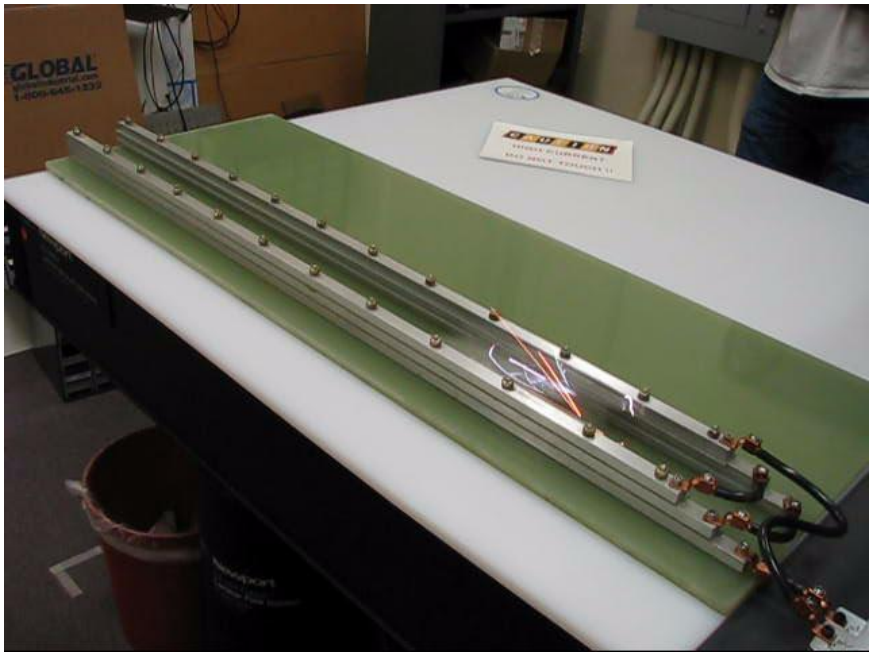
The rest of us have become opportunistic. We've been writing research proposals for both internal and external funding and winning some. We've stayed flexible and have published papers on a wide variety of topics.

Electro-Magnetic Launch Assist

If scramjet or ramjet technology matures then this might be the future…..

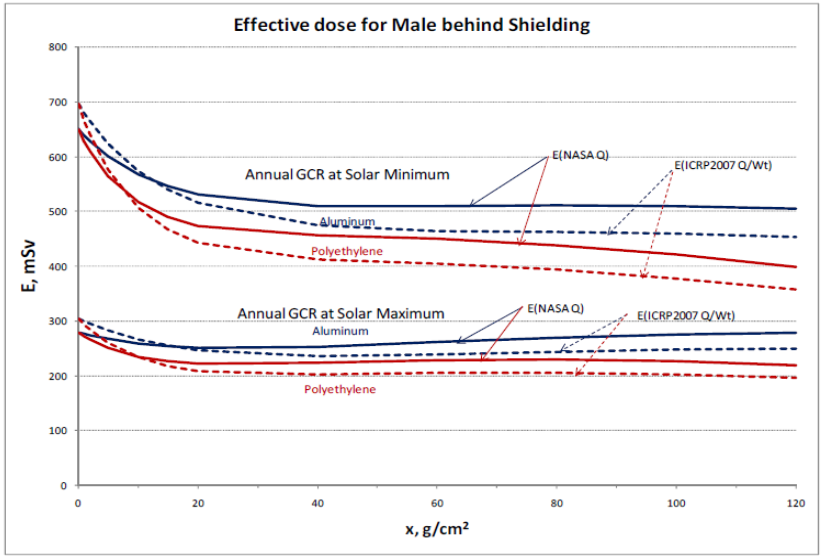
Cheaper access to orbit has been stated as being NASA's #1 priority technology need.
*NASA Space Technology Roadmaps and Priorities (2012), The National Academies.

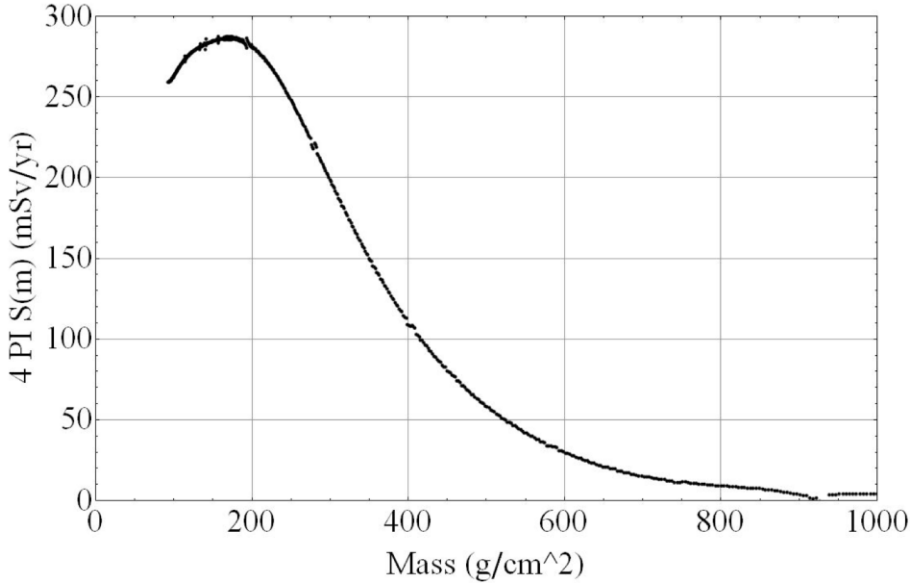
We've been pushing electro-magnetic launch assist, but have been repeatedly rebuffed.



We did obtain some limited funding and demonstrated that a rail gun could be modified to generate controlled low acceleration of vehicle to very high speeds. (Am. J. of Physics, 1/13).

Thick Galactic Cosmic Ray Shielding Using Atmospheric Data





Protecting astronauts from radiation is the number 2 technology priority facing NASA.

*NASA Space Technology Roadmaps and Priorities (2012), The National Academies.

Can you use material to shield the astronauts? Existing GCR shielding models only reached 120 gm/cm^2 and showed that this was not sufficient.

We took FAA GCR data from air flight experiments and inverted this to obtain thick shielding curves. (Acta Astronautica 1/14).

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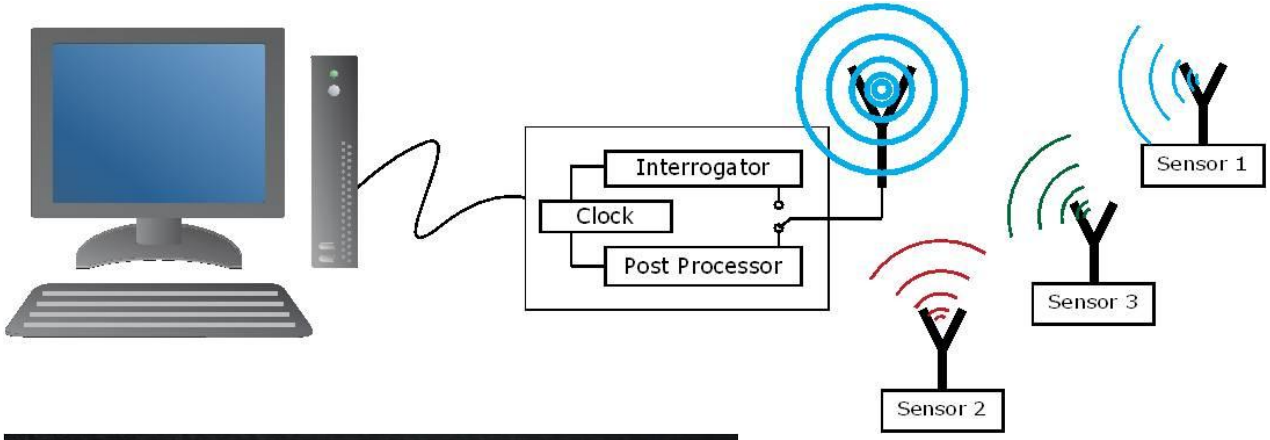
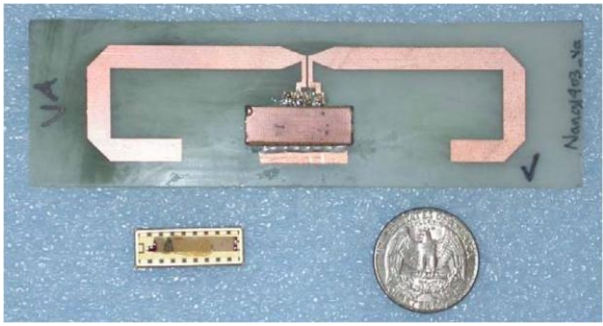
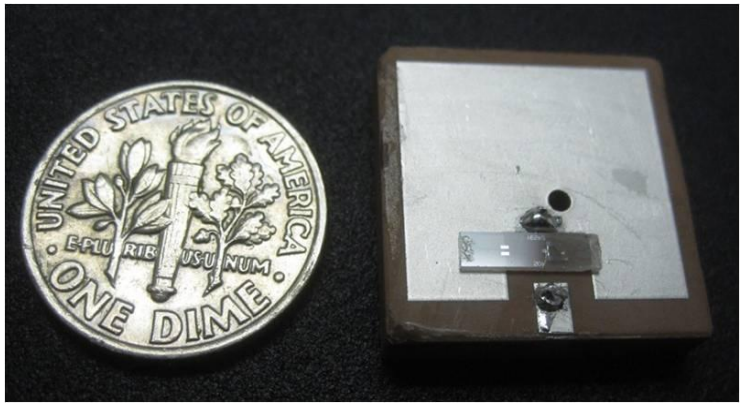
Small Business Space Shuttle Ground Ops. Innovation.







UCF, working with several small businesses and NASA, has developed a multiplexed surface acoustic wave (SAW) wireless, passive, sensing system.

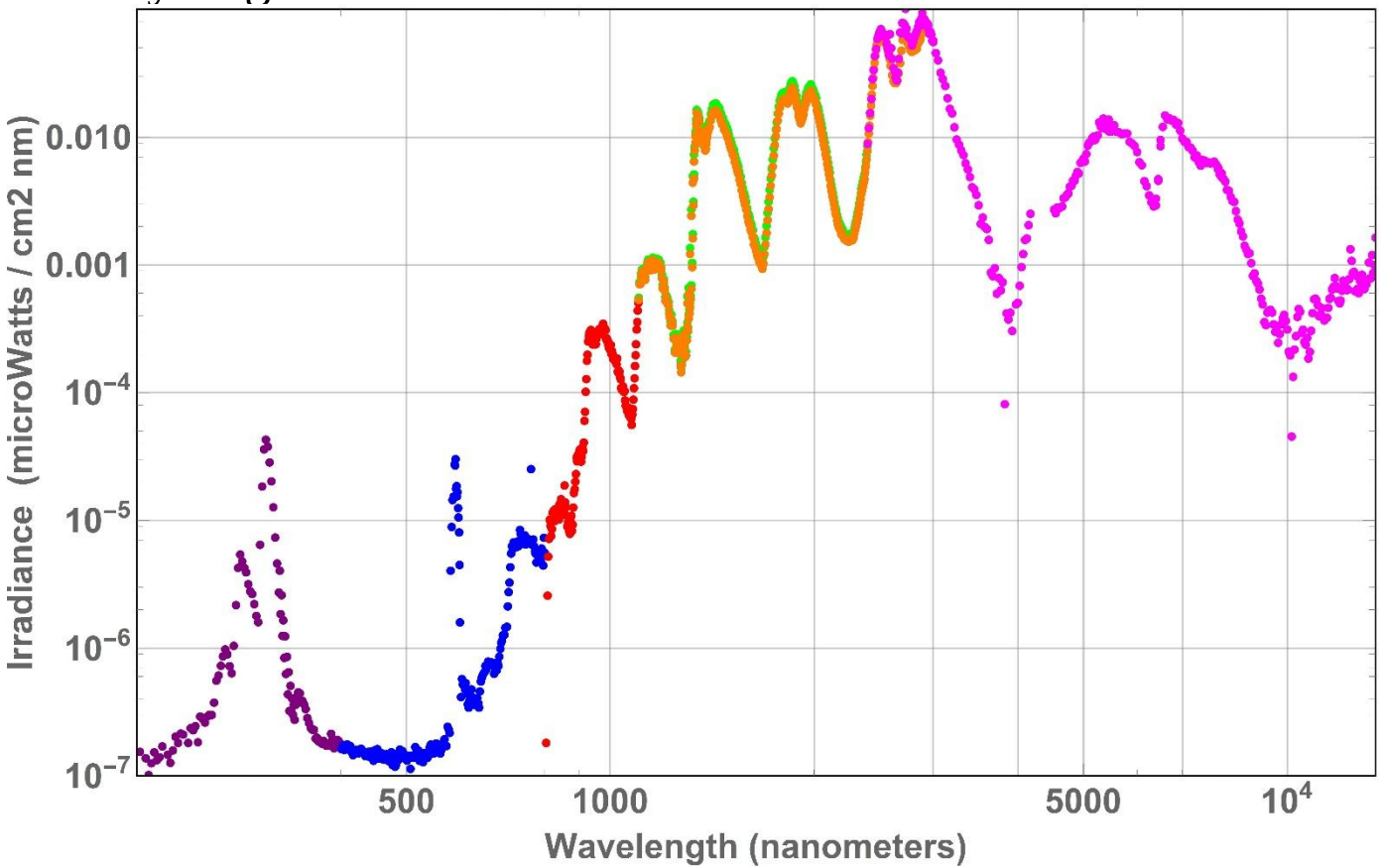
I helped generate a new method for multiplexing these sensors which has been submitted for a patent and had been published.

Calibrated Hydrogen Flame Spectrum

Hydrogen Flames are invisible and required specialized fire detectors operating in either the UV, the near, mid or far-IR.

We measured the actual (NIST)emission of a standard KSC fire (about 2 feet high, low pressure flow, from a distance of 13 feet) in air to help understand the relative performance of various hydrogen flame detectors.

Published in the International Journal of Hydrogen Energy. 6/14.



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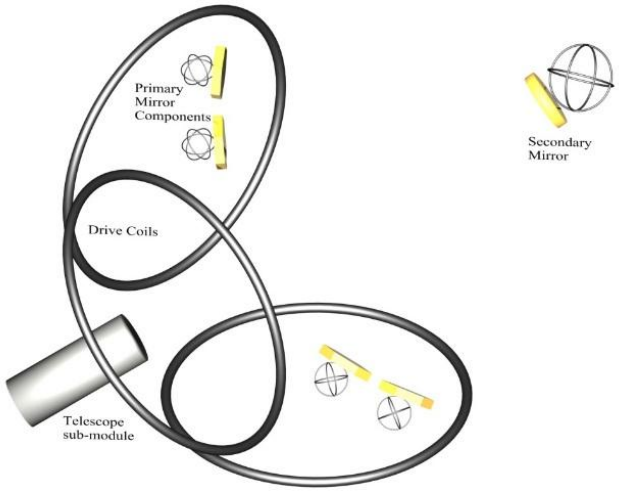
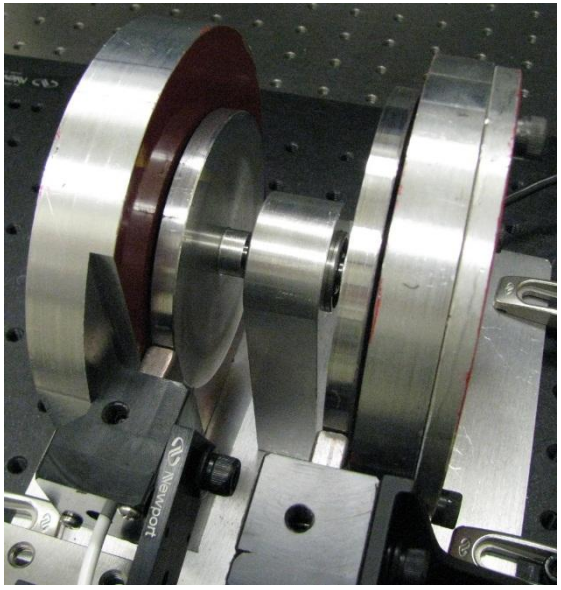
A few more research items we worked on include:

1. An electrostatic galactic radiation shield (Adv. In Space Research 9/08).
2. A spectrometer wavelength calibration concept (Optics Letters, 6/10)
3. A true DC-DC transformer (IEEE Trans. on Power Electronics 1/14)
4. A novel formation flying concept (Acta Astronautica 3/13)
5. A new model for multi-layer insulation (accepted by ASME, J. Thermal Sci. Eng.)
6. A new model for ultra-thin film hydrogen sensors (sub. to IEEE Sensors).





The Future

KSC has an engineering culture, which sometimes clashes with technology development, but the cultural problems are being worked.

We are forming a new R&T directorate at KSC which should help.

Many of the programs are now run by people who saw how technology helped the Shuttle program and they are not adverse to funding new ideas and implementing technology.

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Our ultrasonic leak detection technology was "worth its weight in gold" to the Orion program.

We are currently developing a new generation of hydrogen flame simulators for ground operations.

We are working with the Orion program to establish a flight window certification capability at KSC.

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If the SLS program ramps up there will be new problems and a host of new challenges.