Get Away Special Payload G–093: The VOrtex Ring Transit EXperiment (VORTEX) Flights

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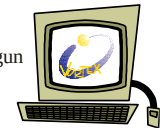
Introduction

- **VORTEX was a student-run project organized by the University of Michigan Students for the Exploration and Development of Space (UMSEDS)**
  - **By designing, building, and flying a GAS payload experiment, UMSEDS members are able to apply their interest in space exploration to a real-world engineering problem which will advance scientific knowledge**
- **VORTEX studied propagation of a vortex ring through a liquid-gas interface in microgravity**
  - **Interesting fluid visualization problem which introduces students to scientific research**
- **G-093 flew on two Shuttle flights: STS-89 in January 1998 and on STS-88 in December 1999**
  - **VORTEX successful and collected scientific data on STS-88**

VORTEX Project Timeline

July 1994	VORTEX Project Begun
	Payload Definition Stage
August 1995	PAR Submitted
	Payload Design
April 1997	VORTEX KC-135 Flights
August 1997	Phase III SDP Submitted
August 1997	SVD Submitted
	VORTEX Final Construction
October 1997	G-093 Integration
22-31 January 1998	STS-89 Mission
February 1998	G-093 De-integration
March 1998	Post-Mission Failure Analysis
	VORTEX Refurbishment
August 1998	G-093R Integration
4-15 December 1998	STS-88 Mission
January 1999	G-093R De-integration
February- 1999	VORTEX Data Analysis Begun



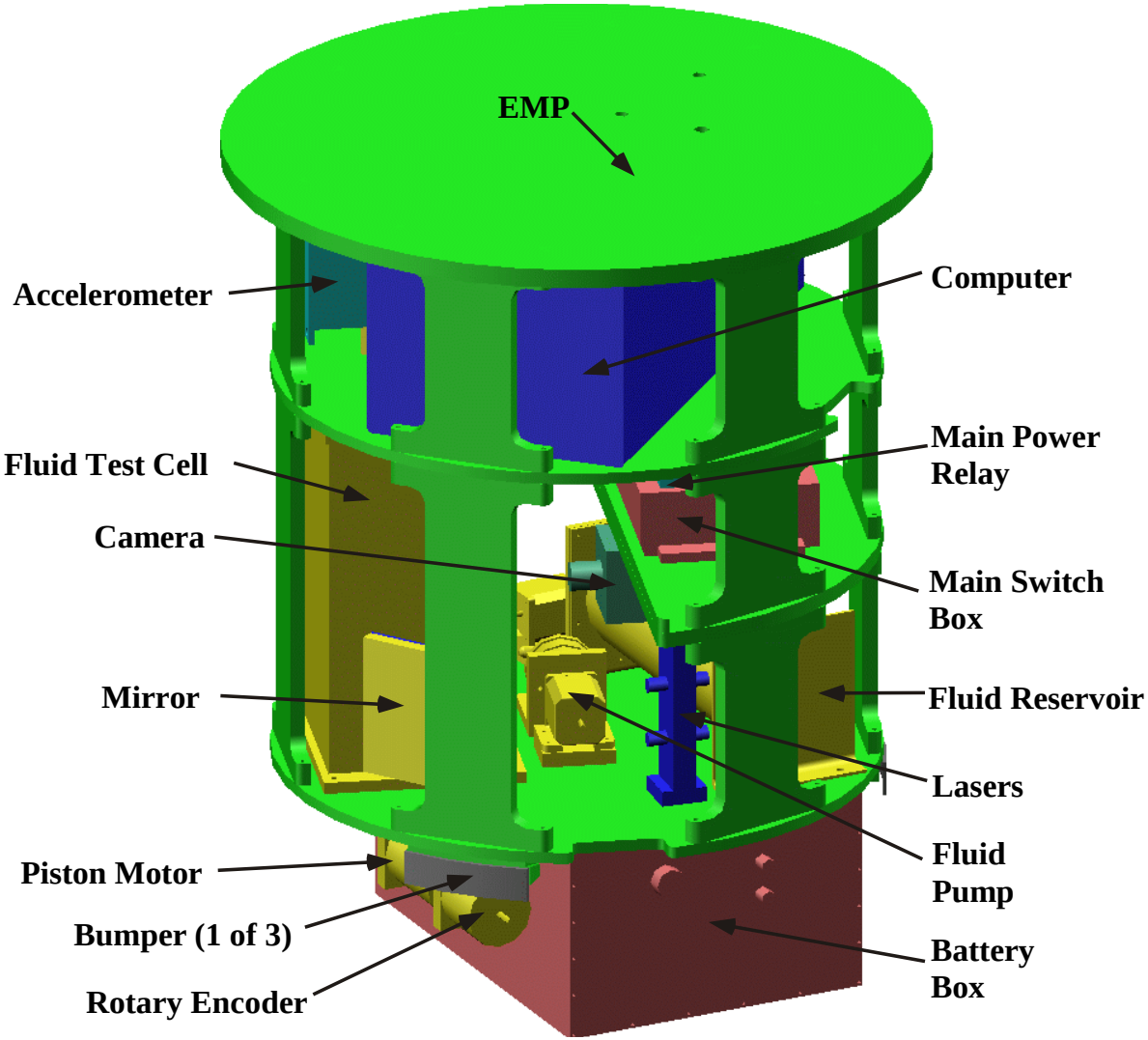
VORTEX Applications

- **Physics of liquid break-up and drop formation by a vortex ring flow in microgravity is a fundamental problem with application to manufacturing and systems development in space**
- **Important in many earth-based engineering systems**
  - **Fuel atomization—the break-up of a liquid stream into small droplets—is an important aspect of the design and operation of internal combustion engines**
  - **Inert gas atomization used in powder metallurgy to produce metal powders of desired characteristics**
  - **Aerosol generators for drug delivery**
  - **Inkjet printer technology**

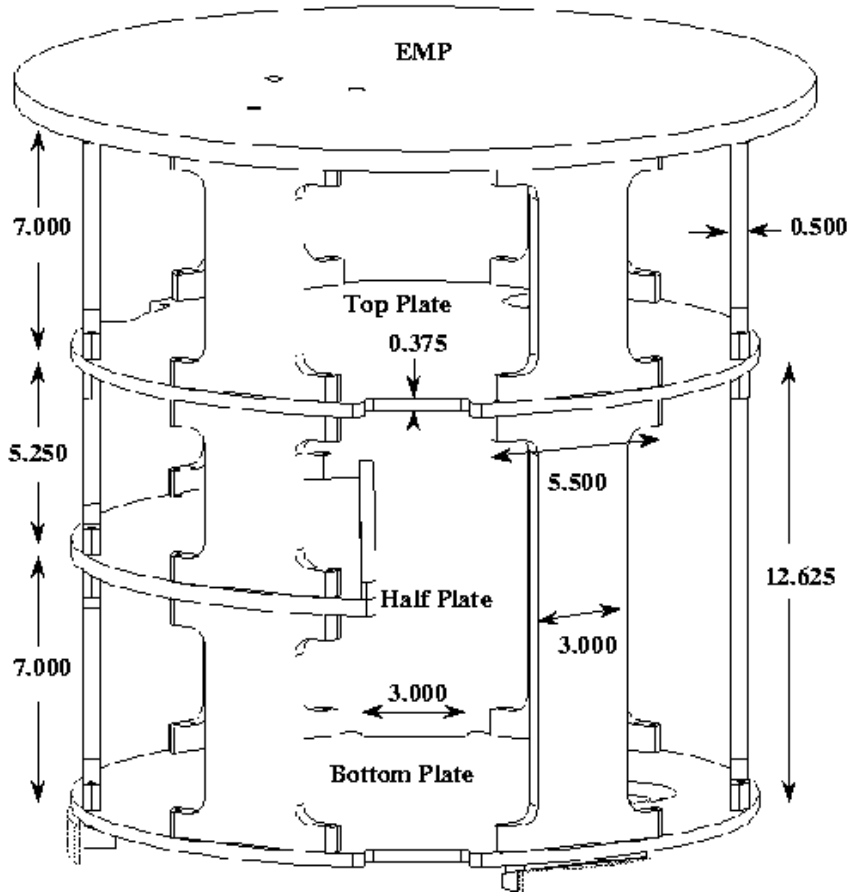
Why Space?

- The microgravity environment is very different from the environment found on the surface of the Earth
- In the microgravity conditions of space, the shape and evolution of fluid interfaces are dominated by surface tension effects, not gravity as on earth
- The microgravity environment represents an opportunity to study surface-tension-dominated phenomena relevant to many earth-based engineering systems such as fluid-atomization processes

Experiment Component Overview

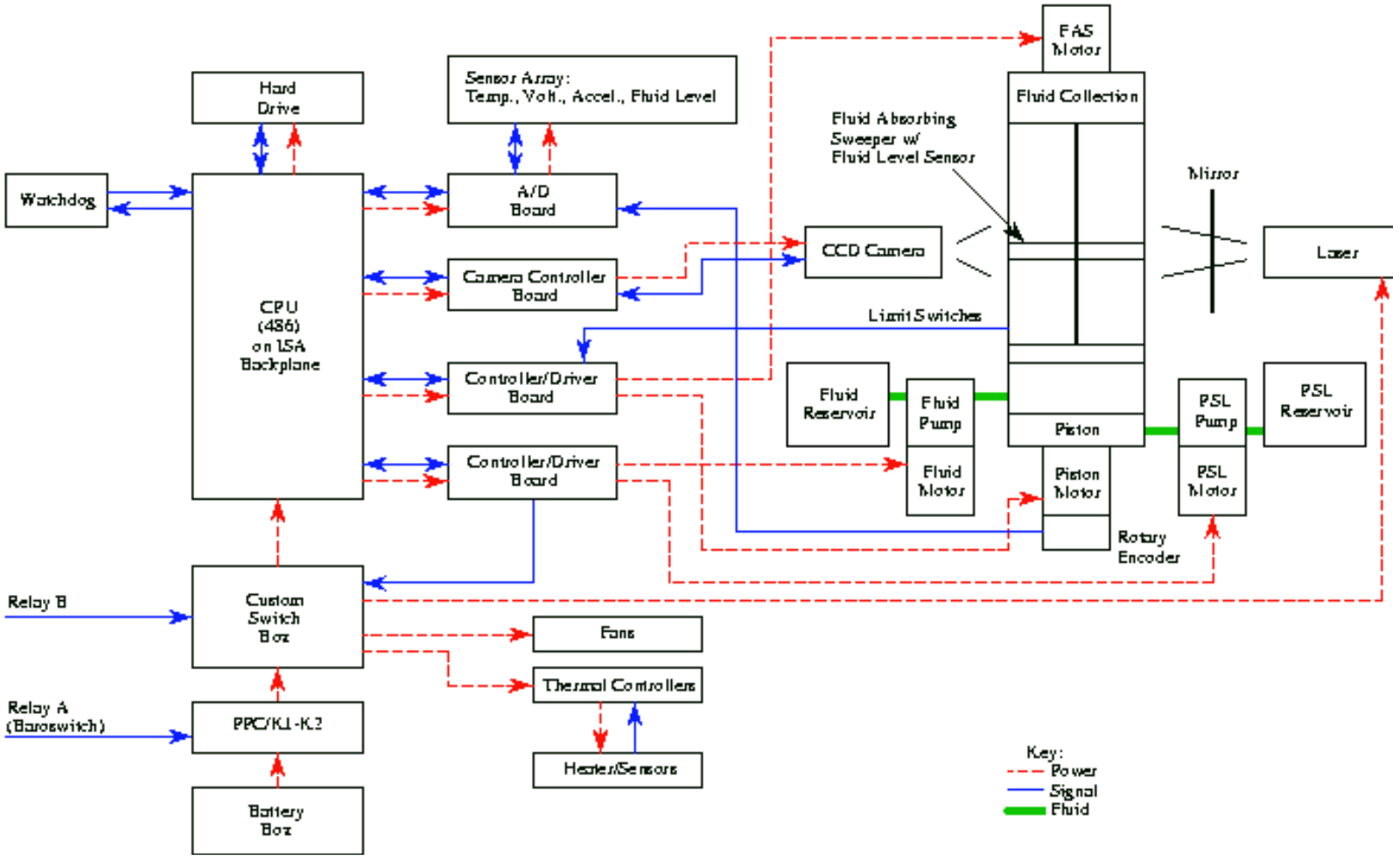


Equipment Support Structure

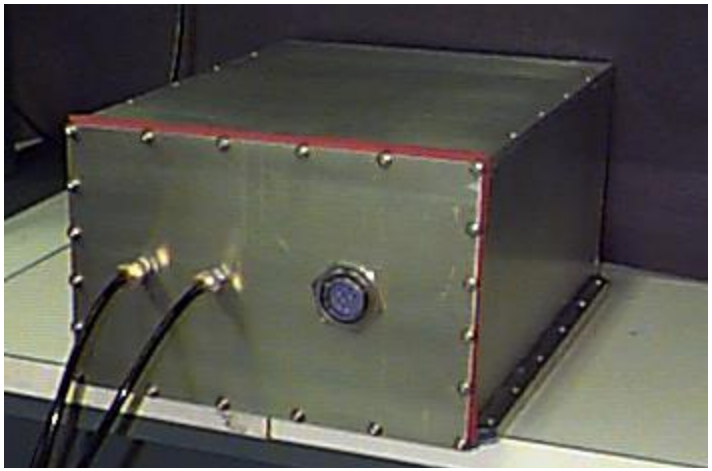


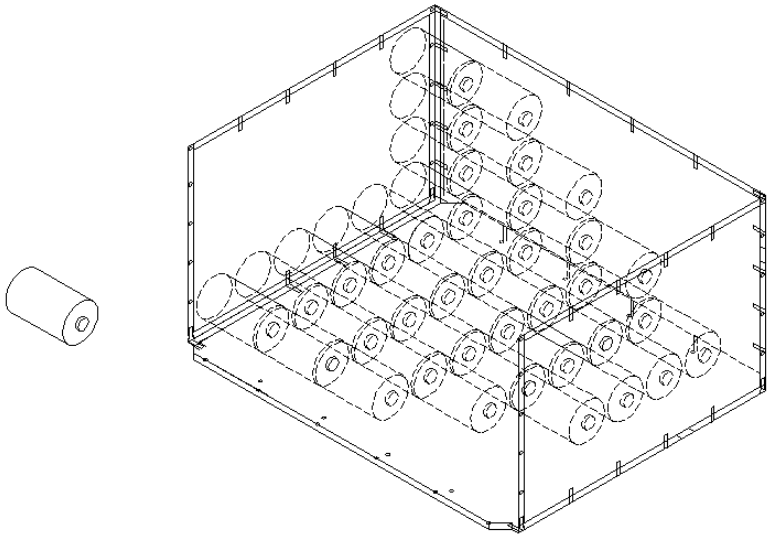
- Two complete shelves and one half shelf
- "I"-shaped support beams allow for easy access to components
- Viton covered bumpers tightened from bottom
- Material: 6061-T6 aluminum
- Mass: 23 kg

Systems Diagram



Battery Box





- Power provided by 120 Alkaline-Manganese Dioxide (Zn/MnO_2) 1.5-V, D-cell batteries
  - Inexpensive
  - 6 parallel strings
  - Each string separately wrapped in shrink tubing
  - Pellon used as shock absorber
- 6061-T6 aluminum box coated with Conathane EN-11
- Total installed energy: 2565 Wh

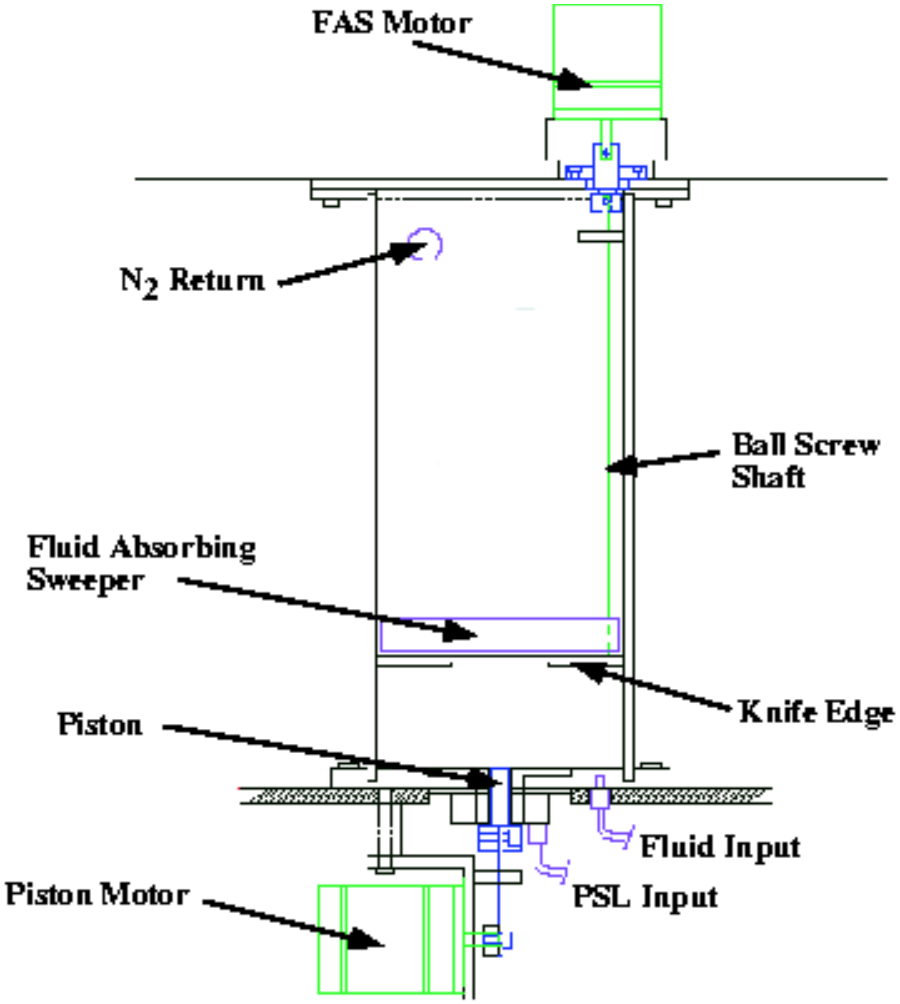
Electrical System

- **Baroswitch activates GCD Relay A**
  - **Upon activation, power provided to heater controllers**
  - **Heaters used to keep components above 0 °C**
- **Payload sequence began when GCD Relay B switched HOT**
- **DC/DC converters generated ±12 V and ±5 V required by payload components**
- **Passive backplane powered computer boards**
- **Power routed to other components through relay boxes**

Experiment Controller and Data Acq.

- Computer system controlled the experimental sequence of events
- COTS hardware
  - 486 processor board on passive backplane
  - Camera board
  - Motor controller boards (2)
  - A/D acquisition board
- More on computer system in companion paper

Fluid Test Cell



- Test cell empty during launch, filled when Relay B HOT
- Knife edge to stabilize fluid
- Vortex ring generator (piston) driven by stepper motor
- Fluid absorbing sweeper periodically cleared test cell
  - Frame with PVA absorbent material
- Liquid used: silicone oil (2-cSt viscosity)
  - Non-conductive
  - Very low freezing temperature (much less than -100 °C)

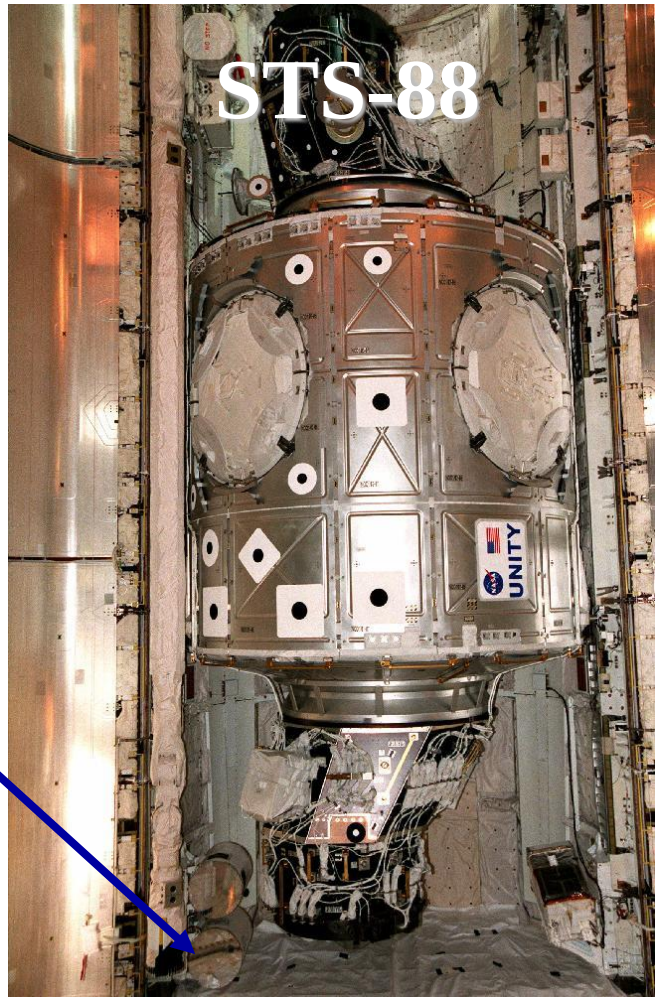
KC-135 Test Flights

- Tests conducted through 1997 NASA Reduced Gravity Student Flight Opportunities Program
- Microgravity provided by KC-135 allowed verification of critical components

VORTEX Shuttle Flights

	STS–89	STS–88
Mission and Emblem		
Location	Bow, Starboard Location of Bay 13	Aft, Port Location of Bay 13
Shuttle Launch	22 January 1998, 21:48:15 EST	4 December 1998, 03:35:34 EST
Experiment Sequence Started	Attempted at STS MET 003/12:26	STS MET 00/04:29
Experiment Sequence Ended	Never Began	STS MET 00/09:39
Payload Shut Off	STS MET 004/10:51	STS MET 00/14:01
Shuttle Landing	31 January 1998 at 17:35:09 EST	15 December 1998, 22:53:29 EST

G-093 Locations



Summary

- VORTEX was a student-run project that provided "real-world, hands-on" experience for students
- VORTEX studied propagation of a vortex ring through a liquid–gas interface in microgravity
- G-093 flew on two Shuttle flights: STS-89 in January 1998 and STS-88 in December 1999
- VORTEX successful and collected scientific data on STS-88
- More info can be found on the VORTEX Website `http://aoss.engin.umich.edu/vortex`

VORTEX Sponsors

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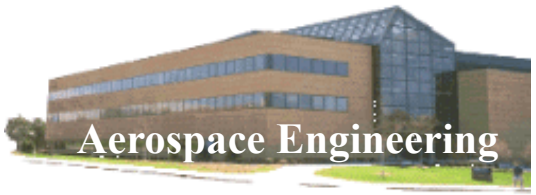

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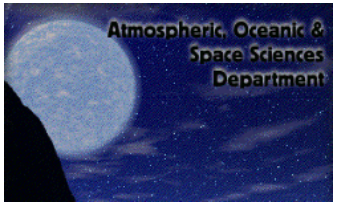

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