MICROMETEOROIDS AND DEBRIS

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SCOPE

• WHAT MATERIALS ARE VULNERABLE?
  - ALL VULNERABLE TO HYPERVELOCITY IMPACTS
  - IMPORTANCE OF IMPACT EFFECT DEPENDS ON FUNCTION OF MATERIAL:
    = MIRROR (EROSSION)
    = PRESSURE VESSEL (EXPLOSION)

• LEO MOST SIGNIFICANT REGION RELATIVE TO ORBITAL DEBRIS
  - METEOROID ENVIRONMENT INDEPENDENT OF ORBIT
  - RELATIVE VELOCITIES DEBRIS IN GEO ARE LOW

• CONSEQUENCES OF ENVIRONMENT EFFECT
  - SMALL SIZES-DEGRADATION
  - LARGE SIZES-CATASTROPHE
CORRELATION BETWEEN LAB/THEORY AND ACTUAL EFFECTS

- HYPERVELOCITY IMPACT MEASUREMENTS SIMULATE DEBRIS IMPACTS
  - SMALL PARTICLES (< 100 MM) TO 10'S KM/SEC
  - LARGE PARTICLES LIMITED TO 7-8 KM/SEC

- CANNOT SIMULATE MICROMETEOROID IMPACTS VERY WELL
  - VELOCITIES TO 40 KM/SEC
  - LOW DENSITY PARTICLES

- MASSIVE COLLISIONS CAN BE SCALED AND MODELED
  - MAJOR EFFECTS PREDICTED
  - SIZE AND VELOCITY DISTRIBUTION OF SMALL PARTICLES NOT WELL KNOWN

RELATED TOPICS

- STUDY OF IMPACTS/COLLISIONS IN SPACE
  - GROUND-BASED, SPACE-BASED (IF POSSIBLE) OBSERVATIONS - SIZE AND VELOCITY OF DEBRIS
  - "MISSIONS OF OPPORTUNITY"

- MITIGATION MEASURES
  - SWEEPING SMALL DEBRIS
  - AVOIDANCE MANEUVERS
  - MOVABLE SHIELS
  - REMOVAL OF LARGE OBJECTS
  - IMPROVED SPACECRAFT PAINT
  - OPERATIONAL PROCEDURES TO MINIMIZE BREAKUPS
FLIGHT EXPERIMENT POSSIBILITIES

ENVIRONMENT DEFINITION

- NON-RETRIEVABLE SATELLITES (SOURCE ID DIFFICULT)
  - 1 MM AND LARGER - QUICKSAT ($100M)
  - BELOW 1 MM
    = OFF-THE-SHELF SENSORS
    = EXISTING/PLANNED EXPERIMENTS (SERTS, EOIM)

- RETRIEVABLE SATELLITES (SOURCE ID POSSIBLE)
  - LDEF RECOVERY
  - FREE-FLYER "GAS-CAN"
    = EXPANDABLE SURFACES FOR LARGE AREA
    = REGULAR LAUNCHES (2-3 YEAR INTERVALS)

- COSMIC DUST FACILITY FOR SPACE STATION
  - > 10 YEARS AWAY

SPACE EXPERIMENT REQUIREMENTS

- ENVIRONMENT FOR SIZES BELOW 10 CM POORLY DEFINED
  - UNCERTAINTY FACTORS OF 3 TO 10 FOR DEBRIS
  - RAPID CHANGES OF DEBRIS POPULATION ARE POSSIBLE (AND LIKELY)
  - METEOROID ENVIRONMENT DEFINED WELL ENOUGH

- SYNERGISM AND CUMULATIVE EFFECTS NOT WHOLLY PREDICTABLE, AND HENCE MAY NOT ALL BE SIMULATABLE. FLIGHT EXPERIMENT EXERCISES ALL POSSIBILITIES

- CANNOT COMPLETELY SIMULATE/Calculate EFFECTS OF MASSIVE COLLISIONS IN SPACE
SYNERGISTIC EFFECTS

• MANY POSSIBILITIES-RELATIVE IMPORTANCE UNKNOWN

• EXAMPLES
  - ATOMIC OXYGEN EROSION INITIATED BY IMPACT
  - CONTAMINATION INDUCED BY VAPOR FROM IMPACT
  - SPACECRAFT CHARGING EFFECTS FACILITATED BY PENETRATIONS
  - THERMAL EFFECTS PRODUCED BY EROSION OF THERMAL CONTROL COATINGS

• CASCADES CONCEIVABLE

CONFIDENCE LEVEL

• CAN WE BUILD SATELLITES FOR 10-30 YEAR OPERATION?
  - NO FOR LARGE AREA, LONG LIFE SATELLITES
    = DEBRIS ENVIRONMENT NOT WELL ENOUGH KNOWN
  - NO FOR SATELLITES WITH NEW FUNCTIONS
    = DON'T KNOW SYNERGISTIC EFFECTS AND THEIR IMPORTANCE
  - YES FOR SATELLITES OF CONVENTIONAL DESIGN AND FUNCTION
FLIGHT EXPERIMENTS NEEDED

- FIRST PRIORITY: MEASURE LEO ENVIRONMENT FOR SIZES BELOW 1 CM (GROUND-BASED RADARS TO COVER > 1 CM OBJECTS)
  - VITAL DATA FOR DETERMINING SIGNIFICANCE
- SECOND PRIORITY: REPEAT THE MEASUREMENTS AT INTERVALS TO MONITOR CHANGES
- THIRD PRIORITY: ESTABLISH NATURE AND SIGNIFICANCE OF POSSIBLE SYNERGISTIC EFFECTS
- FOURTH PRIORITY: UNDERSTAND DETAILS OF MASSIVE COLLISIONS IN ORBITS (BETTER DEFINITION OF ENVIRONMENT)

FLIGHT EXPERIMENT POSSIBILITIES

SYNERGISM/ACCUMULATED EFFECTS

- NEED LONG-TERM EXPOSURE OF REAL SYSTEMS
- RECOVERY OF OLD SATELLITES FOLLOWED BY DETAILED INTERDISCIPLINARY ANALYSIS
  - LDEF - 5 YEARS OLD, CAPTURE PLANNED NOVEMBER 1989
  - SMM, SAGE - 10 YEARS OLD
    = CAPTURE BY SHUTTLE
  - TIROS - 30 YEARS
    = CAPTURE USING ELV
- COSTLY, DIFFICULT TO RETRIEVE SATELLITES
  - NEED INTERDISCIPLINARY JUSTIFICATION
- LDEF REMAINS PRIME CANDIDATE FOR RECOVERY
  - MAJOR SOURCE OF NEW DATA