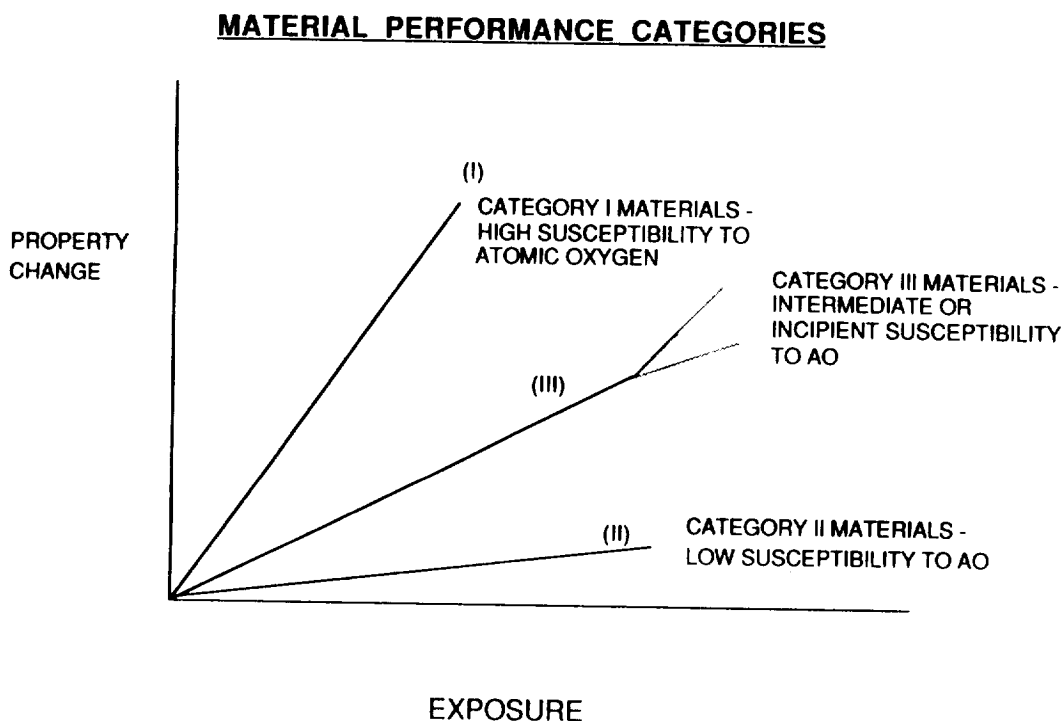


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ATOMIC OXYGEN

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**WHAT MATERIALS ARE MOST VULNERABLE TO
ATOMIC OXYGEN DEGRADATION?**

- CATEGORY I AND III MATERIALS ARE MOST VULNERABLE; CATEGORY II MATERIALS ARE LEAST VULNERABLE
 - FOR SOME APPLICATIONS, EVEN SMALL DEGRADATION DUE TO AO INTERACTIONS MAY BE UNACCEPTABLE
 - MOST SENSITIVE ORBITS ARE THOSE LEO ORBITS WHERE AO NUMBER DENSITIES VARY BETWEEN 10^5 - 10^9 ATOMS/CM³
 - DEGRADATION EFFECTS VARY IN RELATION TO EXPOSURE TIME (FLUENCE)
 - MATERIAL APPLICATIONS AND SYSTEM PERFORMANCE REQUIREMENTS DETERMINE EXPOSURE CONDITIONS
 - PROLONGED EXPOSURE OF SENSITIVE MATERIALS WILL RESULT IN DEGRADED SYSTEM PERFORMANCE OR REQUIREMENTS FOR ON-ORBIT MAINTENANCE; BOTH CONDITIONS CONTRIBUTE TO INCREASED MISSION COST AND REDUCED MISSION OBJECTIVES

MATERIAL CLASSES FOR SPACECRAFT APPLICATIONS

<u>MATERIAL CLASS</u>	<u>PERFORMANCE CATEGORY</u>
• ORGANIC FILMS	I-II
• INORGANIC	II
• SILICONE PAINTS	II
• LUBRICANTS	I-II-III
• ORGANIC ADHESIVES	I
• ORGANIC COMPOSITES	I
• METAL MATRIX COMPOSITES	II
• THERMAL CONTROL COATINGS	I-II-III
• OPTICAL COATINGS	I-II-III

SPACECRAFT ORBITS SENSITIVE TO AO INTERACTIONS

- MINIMUM ALTITUDE IS 100 KM
- MAXIMUM ALTITUDE IS 700 KM, ALTHOUGH VERY SENSITIVE SYSTEMS MAY BE AFFECTED AT HIGHER ALTITUDES
- WHY? -- OXYGEN ATOM CONCENTRATIONS ARE DOMINANT WITHIN THESE ALTITUDE RANGES

CORRELATION OF AO EFFECTS ON MATERIALS

- LABORATORY AND FLIGHT EXPERIENCE REPRESENT RELATIVELY IMMATURE DATA BASE
 - FLIGHT DATA LIMITED IN FLUENCE AND ACCURACY OF FLUENCE ESTIMATES
 - LABORATORY SIMULATIONS ONLY RECENTLY AVAILABLE
 - QUALITATIVE CORRELATION OF LABORATORY AND FLIGHT DATA FOR VERY LIMITED NUMBER OF MATERIALS (REACTION EFFICIENCIES AND MORPHOLOGY CHANGES, ACTIVATION ENERGY)
- FUTURE FLIGHT EXPERIMENTS TO PROVIDE ACCURATE REACTION RATE MEASUREMENTS FOR COMPARISON TO GROUND-BASED RESULTS

CORRELATION OF SPACECRAFT GLOW EFFECTS

- CORRELATION BETWEEN GLOW FLIGHT EXPERIMENTS AND LABORATORY RESULTS
 - VISIBLE EMISSIONS
 - = MEASURED SPECTRUM SIMILAR TO LABORATORY NO₂
 - = PREDICTED PHENOMENA VERY DIFFICULT TO SIMULATE
 - = EFFECTS OF SURFACE PROPERTIES ON RECOMBINATION EFFICIENCY (INCLUDING STICKING EFFICIENCIES VS T_s) NEEDS STUDY
 - UV EMISSIONS
 - = MEASURED SPECTRUM (1400-1800) SIMILAR TO LABORATORY SURFACE RECOMBINATION (N₂ -LBH)
 - = NO GOOD FLIGHT UV DATA BASE
 - = PREDICTED PHENOMENOLOGY (1-5 EV N₂ ON SURFACE) HAS NOT BEEN DONE
 - IR EMISSIONS
 - = FLIGHT DATA SPARCE
 - = LABORATORY EXPERIMENTS OF MANY PREDICTED PHENOMENA CAN BE SIMULATED

DO WE KNOW ENOUGH TO LAUNCH FOR 10-30 YEARS OF SERVICE WITH CONFIDENCE?

- NO FLIGHT OR LABORATORY DATA BASE FOR FULL LIFE EXPOSURE; LIMITED EXPOSURE ONLY
- MATERIALS ARE AVAILABLE THAT APPEAR TO BE NON-REACTIVE TO AO
 - LIMITED KNOWLEDGE PLACES SEVERE CONSTRAINTS ON SYSTEM DESIGN
 - EACH APPLICATION REQUIRES SPECIAL CONSIDERATIONS AND UNDERSTANDING OF SYNERGISTIC EFFECTS
 - DESIGN SOLUTIONS FOR 5-YEAR LIFE HAVE BEEN DEVELOPED
 - ACCELERATED, FULL-LIFE TESTING OF PROTECTIVE COATING CONCEPTS TO BE CONDUCTED IN GROUND-BASED LABORATORIES
- SYNERGISTIC EFFECTS NOT ADEQUATELY UNDERSTOOD

ARE TERRESTRIAL LABORATORY FACILITIES ADEQUATE?

- AT LEAST TWO AO-BEAM FACILITIES HAVE ADEQUATE SIMULATION CAPABILITY

PHYSICAL SCIENCES CORP.

STRENGTHS

- LARGE BEAM (30-1,000 CM²)
- MULTIPLE SAMPLES
- HIGH ENERGY (5-12 EV)
- LONG EXPOSURES POSSIBLE
- HIGH FLUX (10¹⁸ - 10¹⁶ ATOMS/CM²)
- FLUENCE UP TO 10²¹ ATOMS/CM² HAVE BEEN ACHIEVED

WEAKNESSES

- PULSED SOURCE
- HIGH INSTANTANEOUS FLUX

LOS ALAMOS

- | | |
|---|---|
| • CONTINUOUS BEAM | • SMALL BEAM |
| • HIGH ENERGY (1-5 EV) | • CONTAINS O ₂ , INSERT GAS, 0* AND UV |
| • HIGH INTENSITY (10 ¹⁷ ATOMS/CM ²) | |
| • LONG EXPOSURES (76 HRS) | |
| • FLUENCES TO 2 X 10 ²² ATOMS/CM ² HAVE BEEN ACHIEVED | |

- OTHER FACILITIES BEING DEVELOPED
- NEED TO PROVIDE HIGH QUALITY SIMULATION FACILITY TO COMMUNITY FOR MATERIAL EVALUATIONS

SYNERGISM WITH OTHER FACTORS

- SYNERGISM WITH OTHER FACTORS IMPORTANT RELATIVE TO MATERIAL EFFECTS
- MOST IMPORTANT APPEAR TO BE DAMAGE TO PROTECTIVE COATINGS FOLLOWED BY REACTION WITH SUBSTRATE
 - RADIATION INDUCED FAILURE OF COATING
 - MICROMETEOROID/SPACE DEBRIS (SMALL PARTICLES)
 - THERMAL CYCLING
 - CHARGING DAMAGE
- ACCELERATION OF REACTION RATES
- GLOW SYNERGISM WITH OTHER FACTORS
 - SURFACE CONTAMINATION
 - GAS RELEASES OF REACTIVE PRODUCTS
- HAS SYNERGISM BEEN TESTED OR EVALUATED?
 - INITIAL CONSIDERATION OF COUPLING, BUT VERY LIMITED EVALUATIONS
 - LABORATORY FACILITIES WITH COMBINED ENVIRONMENTS NOT AVAILABLE

NEED FOR SPACE EXPERIMENTS

- SPACE EXPERIMENTS ARE NEEDED FOR MATERIAL INTERACTION ASSESSMENT
 - VALIDATION OF GROUND-BASED MATERIAL EVALUATION SYSTEMS
 - ESTABLISH MATERIAL REACTION DATA BASE
 - ENHANCED UNDERSTANDING OF INTERACTION MECHANISMS LEADING TO CONFIDENCE IN DESIGN
- GLOW SPACE EXPERIMENTS ARE NEEDED
 - ESTABLISH DATA BASE ON GLOW CHARACTERISTICS ACROSS SPECTRAL REGIONS OF INTEREST
 - VALIDATED EXISTING MODELS

PROPOSED EXPERIMENTS

- LDEF RETRIEVAL
 - EXPANSION OF DATA BASE
 - HIGH FLUENCE EXPOSURE (1×10^{21} ATOMS/CM²)
 - FLUX EFFECTS (LOW FLUX OVER LONG EXPOSURE)
 - HARDWARE ASSESSMENTS
- EOIM-3
 - BENCHMARK REACTION RATE DATA BASE USING ON-BOARD MASS SPECTROMETER
 - DATA FOR CORRELATION WITH GROUND SIMULATION SYSTEMS
- DELTA STAR
 - ACTIVE SENSOR DEVELOPMENT AND PERFORMANCE ASSESSMENT
 - CORRELATION WITH GROUND-BASED SIMULATION FACILITIES
- SMALL SATELLITES (INCLUDING LDEF)
 - ORIENTATION CONTROLLED
 - REAL TIME DATA
 - RECOVERY (IN SOME CASES)
 - DEPLOY IN DIFFERENT ORBITS INCLUDING HIGH ALTITUDE, LONG EXPOSURES

PROPOSED EXPERIMENTS (CONTINUED)

- LDEF REFLIGHT
 - REAL TIME TELEMETRY DATA
 - EVALUATE ADVANCED MATERIAL CONCEPTS
- SATELLITE RETRIEVAL
 - RECOVERING EXISTING SATELLITES FOR POST-MISSION INSPECTION
 - SATELLITE ORBITS MAY NOT BE COMPATIBLE WITH STS MISSIONS--MAY REQUIRE SPECIAL PROVISION FOR SHUTTLE RECOVERY
- SPACECRAFT GLOW
 - NASA OAST OUTREACH EXPERIMENT
 - INFRARED GLOW MEASUREMENTS
 - CIV GLOW EFFECTS
- DEVELOPMENT OF LOW-COST SATELLITE BASE AND ACTIVE SENSORS

EXPERIMENT CHARACTERISTICS

- MATERIAL EFFECTS EXPERIMENTS
 - LONG DURATION EXPOSURES
 - CONTROLLED SPACECRAFT ORIENTATION
 - DISTURBANCE INDEPENDENT
 - PROVISIONS FOR ELECTRICAL POWER
 - TELEMETRY
 - GOOD CONTROL OF CONTAMINATION
- GLOW INVESTIGATIONS--SAME REQUIREMENTS AS MATERIAL EFFECTS, EXCEPT:
 - ELLIPTICAL ORBITS
 - LONG DURATION DURATION EXPOSURES NOT NECESSARY

VOLUME, WEIGHT, AND COMPLEXITY OF EXPERIMENTS

- MATERIAL EXPERIMENTS

- EOIM-3
 - WEIGHT--1,000 LBS, WITH STS CARRIER
 - VOLUME--1/8 SHUTTLE PAYLOAD BAY
 - COMPLEXITY--MODERATE
COMPLEXITY (RAM ORIENTATIONS REQUIRED)
- LDEF
 - PREVIOUSLY DESCRIBED
- DELTA STAR
 - WEIGHT--50 LBS
 - VOLUME--SEVERAL CUBIC FEET
 - COMPLEXITY--LOW (ACTIVE TRAY)
- SPACECRAFT GLOW
 - WEIGHT--1,000 LPS, WITH STS CARRIER
 - VOLUME - 10 CUBIC FEET