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ORBITER LESSONS LEARNED
A GUIDE TO FUTURE VEHICLE DEVELOPMENT

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by Rockwell International - H. Stan Greenberg

Need - Wind persistence loads methodology

BACKGROUND

- o SPACE SHUTTLE WAS DESIGNED TO A SYNTHETIC WIND ENVIRONMENT FOR HIGH Q PORTION OF FLIGHT
- o LAST WIND MEASUREMENT TAKEN 2 HOURS BEFORE LAUNCH
- o INITIAL ESTIMATES GROSSLY UNDERESTIMATED WIND PERSISTENCE (VARIABILITY)

ACCOMPLISHMENTS

- o THOROUGH ASSESSMENTS OF WIND PAIRS INDICATE THE METHOD OF ANALYSIS IS CRITICAL TO MAGNITUDE OF WIND PERSISTENCE
- o WIND PAIRS CAN BE EVALUATED AT CONSTANT MACH NUMBER, AT PEAK LOAD, OR AT MINIMUM MARGIN

FUTURE NEED

- o ASSURE THAT WIND PERSISTENCE IS PROPERLY DEVELOPED FOR VEHICLE DESIGN
- o USE MINIMUM MARGIN APPROACH IN STATISTICAL DETERMINATION OF PERSISTENCE LOAD INCREMENT AT LAUNCH ASSESSMENT

Need - Emphasize Supportability in Design of Reusable Vehicles

BACKGROUND

- o 1970'S ORBITER DESIGN - SUPPORTABILITY AT KSC REPRESENTS SIGNIFICANT FACILITY (OPF) AND MANPOWER COSTS - TURNAROUND TIME IS APPROXIMATELY 2 MONTHS
- o ALL FUTURE REUSABLE VEHICLES REQUIRED REDUCED SUPPORTABILITY COST AND SOME REQUIRE MORE RAPID TURNAROUND TIME

FUTURE NEEDS

- o EMPHASIZE SUPPORTABILITY ENGINEERING IN INTEGRATED SYSTEMS DESIGN PROCESS - IN PARTICULAR EASE OF SUBSYSTEMS REMOVAL/REPLACEMENT
- o DESIGN FOR EASE OF ACCESS AND INSPECTION - CREATIVELY USE GSE
- o EMPHASIZE DURABILITY AND MAINTAINABILITY IN STRUCTURES MATERIALS, CONSTRUCTION, AND CONFIGURATION DESIGN
- o DEVELOP NEW AND AUTOMATED INSPECTION TECHNIQUES

Need - Design for Robustness

BACKGROUND

o DESIGN MARGINS ARE SMALL FOR HIGH Q BOOST PHASE

o PRE-FLIGHT PREDICTIONS OF THE PROBABILITY OF HAVING ACCEPTABLE WINDS FOR SAFE LAUNCH WERE LOW ENOUGH TO BE A SIGNIFICANT PROGRAM CONCERN

o EVOLVING MISSIONS WITH NEW PAYLOADS AND TRAJECTORIES ARE IDENTIFYING VENT PRESSURES OUTSIDE CERTIFIED PRESSURE ENVELOPES

ACCOMPLISHMENTS

o DEVELOPED THE CAPABILITY TO MODIFY THE FLIGHT TRAJECTORY AND TO PERFORM REAL TIME ANALYSIS OF THE BALLOON DATA

o PERFORMED DETAILED ANALYSIS FOR EACH MISSION TO ASSESS STRUCTURAL SUITABILITY TO VENT PRESSURE

FUTURE NEED

o A SYSTEMS ENGINEERING APPROACH CONSIDERING ALL ASPECTS OF LAUNCH PROCEDURES, WIND PERSISTENCE, ENTRY AND LANDING AND FUTURE MISSION PARAMETERS TO EFFECT A MORE ROBUST DESIGN - PERFORMANCE VS OPERATIONAL FLEXIBILITY

Need - Improved aerodynamic environment prediction methods for complex vehicles

BACKGROUND

o EARLY FLIGHTS INDICATED UNEXPECTED WING BENDING - ATTRIBUTED TO AERODYNAMIC COMPLEXITY OF MATED VEHICLE AND THRUST PLUME EFFECTS

o WING STRAIN GAGE FLIGHT DATA INDICATED DISCREPANCIES WITH AERODYNAMIC ANALYSIS PREDICTIONS - ATTRIBUTED TO PLUME EFFECTS

o ANALYSIS AND WIND TUNNEL DATA IDENTIFIED NON-UNIFORM PRESSURE DISTRIBUTION AROUND FUSELAGE DUE TO RAPIDLY MOVING SHOCK WAVES

ACCOMPLISHMENTS

o DEVELOPMENT OF ANALYSIS OF MATED VEHICLE WITH PLUME EFFECTS - WIND TUNNEL TESTING WITH PLUMES - UPDATE OF AERODYNAMIC DATA

o INCREASED INTERACTION BETWEEN AERODYNAMICS AND STRUCTURES THROUGH FEM ANALYSIS

FUTURE NEEDS

o DEVELOP RAPID/ACCURATE AERODYNAMIC PREDICTION TOOLS

o IMPROVED TECHNIQUES FOR SCALING OF WIND TUNNEL DATA AND LOW COST FLIGHT INSTRUMENTATION FOR ANALYSIS VERIFICATION

Need- Automated integration of aerothermal, manufacturing, and structures analysis

BACKGROUND

o TPS TILE GAPS AND STEPS INFLUENCE TRANSITION FROM LAMINAR TO TURBULENT FLOW - INCREASED HEATING

o FLIGHT TEMPERATURE MEASUREMENTS INDICATED GRADIENTS IN EXCESS OF PREDICTIONS - CONSERVATIVE MAXIMUM TEMPERATURE PREDICTIONS CAN MASK HIGH GRADIENT CONDITIONS

ACCOMPLISHMENTS

o REFINED THERMAL ANALYSIS CHARACTERIZATION OF TPS GAPS, STEPS AND STRUCTURE MODEL - FLIGHT MEASUREMENT DATA USED

o DEVELOPMENT OF COMPREHENSIVE ANALYSIS METHODOLOGY - MISSION HEATING PARAMETERS TO MARGIN OF SAFETY - PARTIALLY AUTOMATED

FUTURE NEED

o DEVELOP RAPID AND ACCURATE AUTOMATED ANALYSIS FROM MISSION HEATING PARAMETERS AND AERODYNAMIC PRESSURES TO MARGIN OF SAFETY - INCLUDE MANUFACTURING/STRUCTURAL IMPOSED GAPS AND STEPS

Need - Continued development of durable TPS

BACKGROUND

o ORBITER TPS SYSTEMS ACCOMPLISH MISSION PERFORMANCE GOALS WITH LIGHTWEIGHT, STATE OF THE ART BOND-ON FRSI, AFRSI, COATED CERAMIC TILES AND CARBON-CARBON LEADING EDGES

o ORBITER SUPPORTABILITY EXPERIENCE IN REGARD TO DEBRIS IMPACT, WIND RAIN/ EROSION, AND ACTIVITY AT HIGH SYSTEMS MAINTENANCE REGIONS INDICATE THE DESIRABILITY OF MORE DURABLE TPS

ACCOMPLISHMENTS

o DEVELOPED PBI, HTP CERAMIC TILE COATED WITH TUFI AND ACC - SIGNIFICANT INCREASE IN DURABILITY WITH COMPARABLE WEIGHT

FUTURE NEEDS

o SOME VEHICLE SYSTEMS REQUIRE OPERATION IN MUCH MORE SEVERE WIND/RAIN ENVIRONMENTS

o EASE OF REPLACEMENT IS DESIRABLE AND FACILITATES STRUCTURE INSPECTION

o CONTINUE ONGOING DEVELOPMENTS OF MORE DURABLE TILE , METALLICS, BLANKETS AND ACC FOR MINIMUM SUPPORTABILITY

Need - Continued Electronic Documentation of Structural Design and Analysis

BACKGROUND

- o 1970'S ORBITER STRUCTURES DOCUMENTATION COMPRISED OF HAND PREPARED DRAWINGS, ANALYSIS REPORTS, TYPED SPECIFICATIONS - CONSIDERABLE VOLUME OF DOCUMENTS
- o CONTINUING DEVELOPMENT OF INTEGRATED COMPUTER DESIGN TECHNIQUES SUCH AS IDEAS, CATIA, NASTRAN FEM, ANALYSIS SUBROUTINES REDUCE ENGINEERING HOURS BUT ARE IN ELECTRONIC FORM
- o THE MAGNITUDE OF ELECTRONIC DATA FOR A PROGRAM SUCH AS SHUTTLE WILL BE ENORMOUS

FUTURE NEED

- o DEVELOP APPROACHES TO ELECTRONIC DOCUMENTATION THAT ARE FEASIBLE, EFFICIENT AND SATISFACTORY TO BOTH CONTRACTOR AND GOVERNMENT AGENCIES

Need - Landing gear rollout load simulations

BACKGROUND

- o ORBITER AND OTHER AIRCRAFT GEAR SYSTEMS ARE DESIGNED BY MILITARY SPECIFICATIONS AND FAR 25
- o ORBITER EXPERIENCE INDICATES FLIGHT CONTROL AND GEAR SYSTEM COUPLING DURING ROLLOUT CAN IMPOSE GEAR LOADS IN EXCESS OF SPECIFICATION REQUIREMENTS

ACCOMPLISHMENTS

- o ACCURATE FLIGHT CONTROL SYSTEM INCORPORATED INTO LANDING GEAR LOADS SIMULATION
- o MONTE CARLO ASSESSMENT IS PERFORMED TO DETERMINE REALISTIC 3-SIGMA LIMIT LOADS

FUTURE NEED

- o INCLUDE MINIMUM CONTROL SURFACE OSCILLATIONS IN PRELIMINARY LANDING GEAR ROLLOUT LOAD SIMULATIONS TO BOUND CONTROL AND GEAR SYSTEM INTERACTIONS

20 years of Technology development could result in Orbiter Structure of

o ALUMINUM LITHIUM CREW COMPARTMENT

o GRAPHITE /BMI FUSELAGE, WING, TAIL, AND CARGO BAY DOORS (450°F INNER MOLD LINE TEMPERATURE)

o ACC ON LEADING EDGE, NOSE CAP, AND CONTROL SURFACES

o DIRECT BONDED HTP ON LOWER SURFACE (WITHOUT SIP)

o ONTO REMAINING FUSELAGE SURFACES - NEXTEL BLANKET INSULATION OR PBI OR FRSI ACCORDING TO TEMPERATURE LIMITS

o CARBON FIBER OVERWRAPPED PRESSURE VESSELS