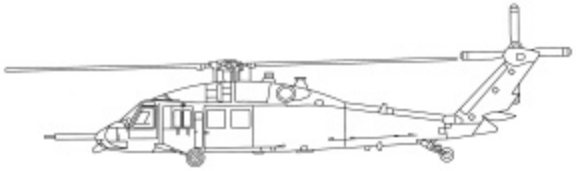

JOINT USAF / ADF S-70A-9 FLIGHT STRAIN SURVEY

PHASE II of a III PHASE AIRFRAME SERVICE LIFT EXTENSION PROG (SLEP)

National Defense Industrial Association
4th Annual
Systems Engineering Conference
Oct 23-25, 2001

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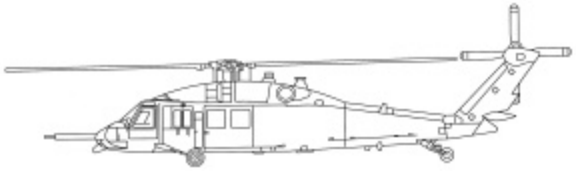
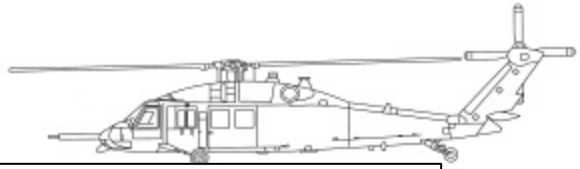


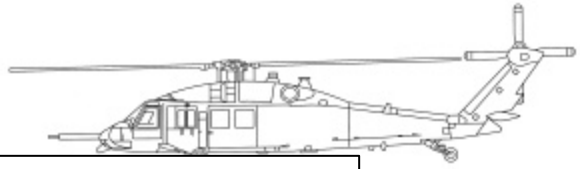
PARTICIPANTS

- DIRECTORATE of AIRWORTHINESS SUPPORT COMMAND AUSTRALIA (ADF SPONSOR)
- WARNER ROBINS AIR LOGISTIC CENTER SOF SYSTEMS PROGRAM OFFICE (USAF SPONSOR)
- AVIATION RESEARCH & DEVELOPMENT UNIT
- SIKORSKY AIRCRAFT CORPORATION & SIKORSKY DEVELOPMENTAL FLIGHT CENTER
- GEORGIA TECH RESEARCH INSTITUTE
- OTHER SUPPORTING SUBCONTRACTORS



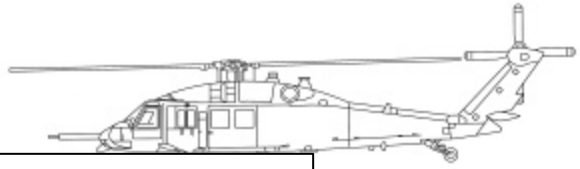
ORDER of PRESENTATION

- PROGRAM OBJECTIVES
- DISTRESSED AREAS in FIELDED AIRCRAFT
- REQUIRED INSTRUMENTATION
- SCOPE of FLT TEST
- POST TEST ANALYSIS
- SUMMARY



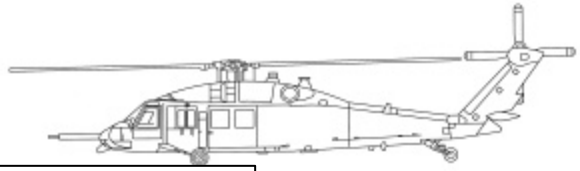
PROGRAM BACKGROUND

- ACC has ESTABLISHED an HH-60G REQT for EXTENDED USE for PRIMARY COMBAT SEARCH and RESCUE (CSAR) MISSION
  - Need for SLEP to Assure an Airframe Safe-Life of 20,000 flt hrs
- UH-60 AIRFRAME STR DESIGN DRIVEN by STATIC STRENGTH, CRASHWORTHINESS & BALLISTIC TOLERANCE CONSIDERATIONS
  - No Airframe Fatigue Life Requirement
  - Airframe Overhaul Interval Not Less Than 8,000 hrs
- UH-60 DYNAMIC COMPONENT RETIREMENT TIMES (CRTs) DESIGN for NOT LESS THAN 5,000 hrs
  - Fatigue Life Greater Than 20,000 hrs Considered Unlimited
- MH/HH-60Gs are POST PRODUCTION MODs of UH-60A/Ls
  - No Airframe Structural Enhancements Incorporated
  - Only Local Attachment of Mission Equipment Considered



HH-60G AIRFRAME FATIGUE

- LIKE OTHER H-60s, NO LIFE LIMIT ESTABLISHED
- HH-60G MISSION USAGE SPECTRUM SURVEY DOCUMENTS LESS STRINGENT ACTUAL USAGE than ARMY SPECTRUM USED for CRT CALCULATIONS
  - 6 A/C Flown, Totaling > 1300 hrs
  - 2 each at Kirtland, Nellis, and Patrick / Moody AFBs
  - Logged Flight Time Averages 15% > Actual Flight Time
- JACE RECORDS for USAF and ARMY U/HH-60s REVEAL SIGNIFICANT HISTORY of AIRFRAME CRACKS and MAINTENANCE DAMAGE
  - Details later in Briefing
  - Approximately 50% of Inventory Aircraft Inspected



HH-60G SLEP PHASES

PHASE ø DETAIL PLANNING

Determine Airframe Fatigue “Hot Spots” from Service Records
Define Instrumentation Reqts with Level I Installation Sketches
Draft Flt Test Plan Details
Formulate Detail Flt Test Cost Estimate

PHASE I STATIC STRENGTH ENHANCEMENTS

Revise Airframe Str Analysis for USAF -152 Avionics Config
End Product -- Level I Dwgs & Str Substantiation Rpt

PHASE II FLIGHT TEST PROG

Both USAF & ADF Reqts
Perform Full Set of Mission Spectrum Maneuvers, both Users
Measure Stress Concentration at/near Distress Areas
End Product-- Data for Loads & Finite Element Model Enhancements

PHASE III FATIGUE STRENGTH ENHANCEMENTS

Uses USAF & ADF Usage Spectra Separately
End Product--Level I Dwgs & Str Substantiation Rpt of Mods

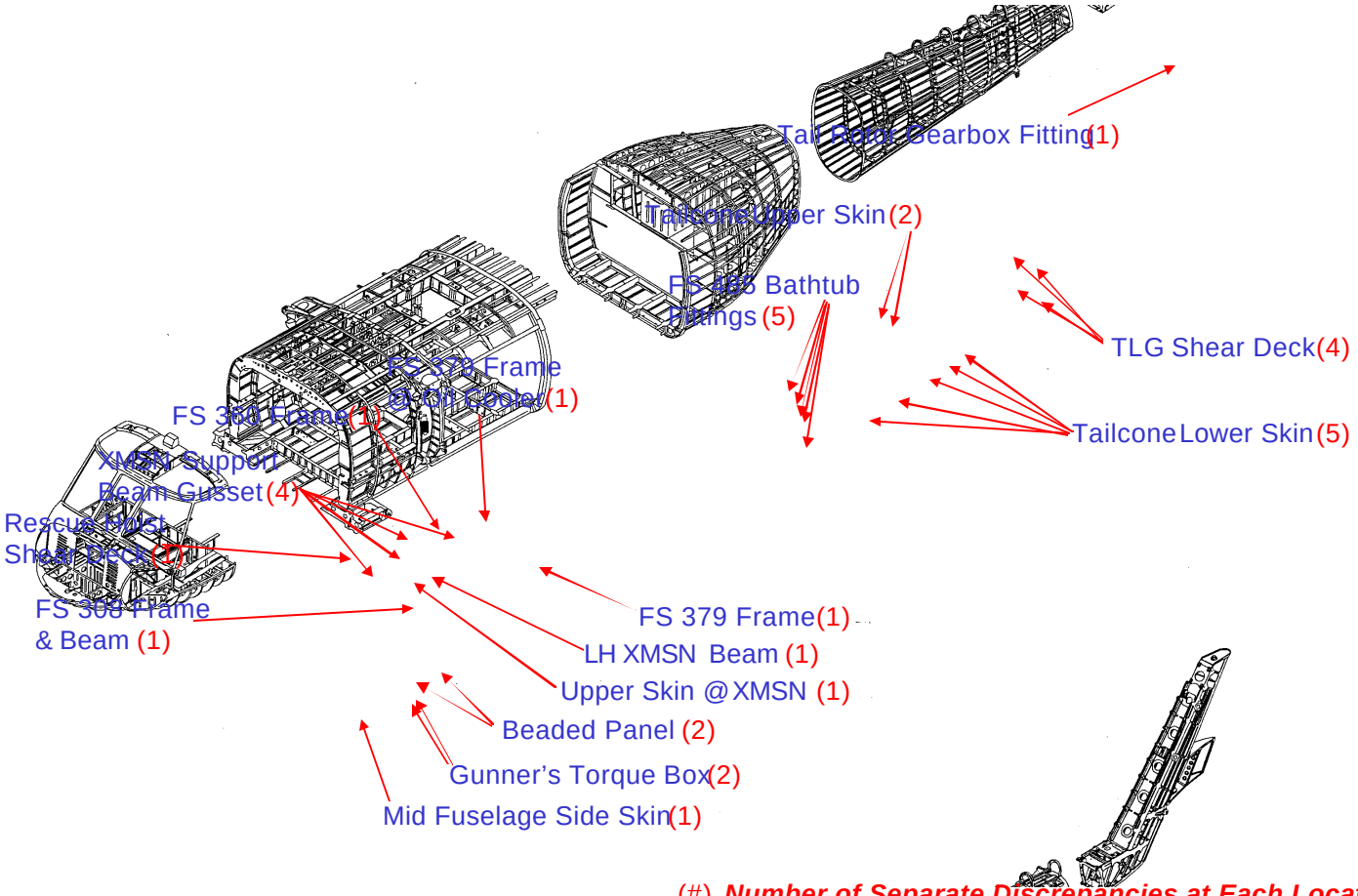
DEFINITION of CRITICALITY CATEGORIES

- **CATEGORY A:** Critical / Major Problems Having Direct Impact on the Airframe Structural Integrity and Safety of Flt (33 Hot Spots - 676 Collective Occurrences)
- **CATEGORY B:** Not Directly Affecting Safety of Flt, but Having Some Impact on Airframe Structural Integrity (45 Hot Spots - 899 Collective Occurrences)

CATEGORY C: Probs Not Directly Affecting Airframe Structural Integrity, but Representing Significant Maintenance Costs (36 Hot Spots - 1013 Collective Occurrences)

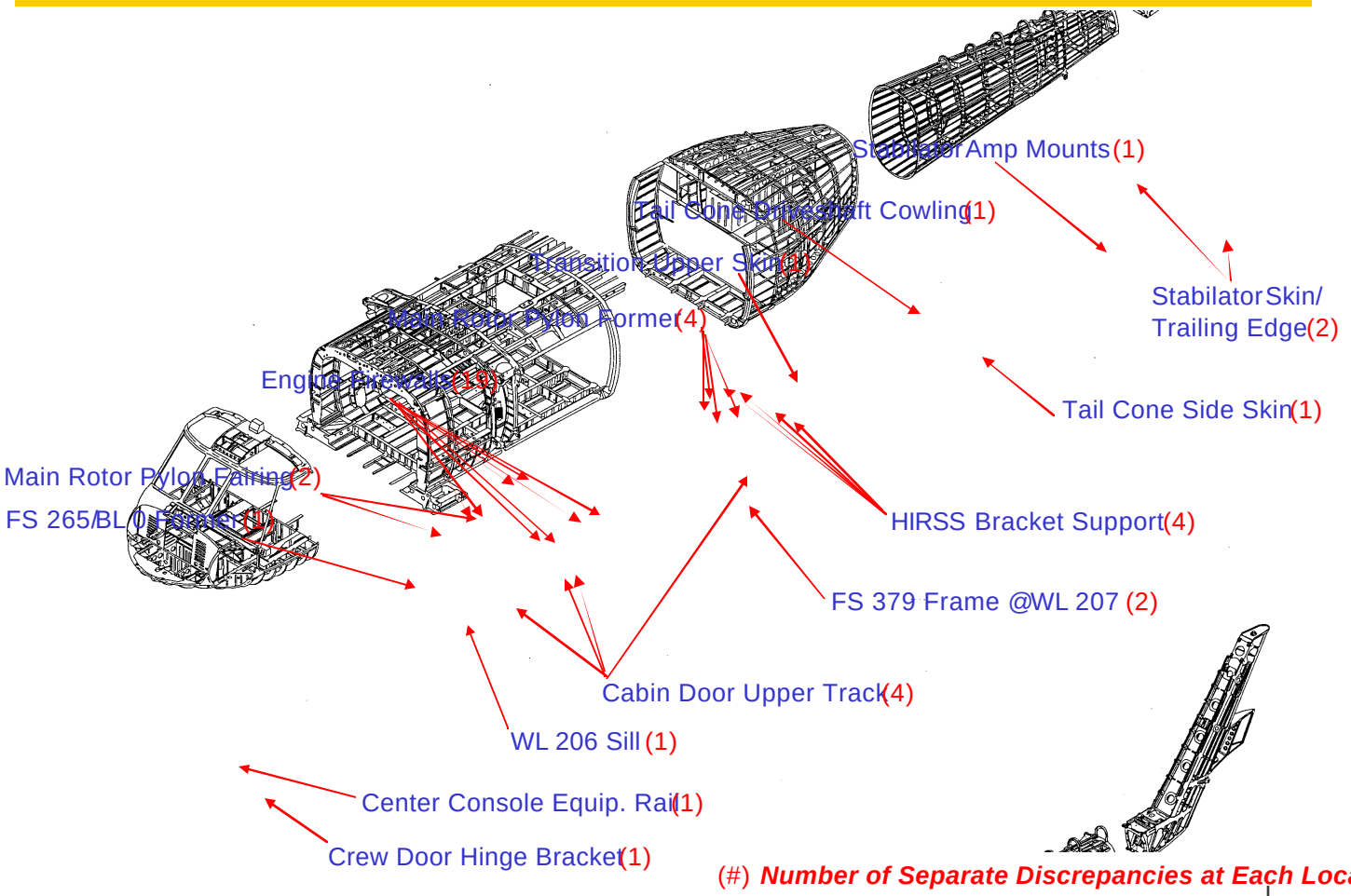
TOTAL = 114 HOT SPOTS, 2588 COLLECTIVE OCCURRENCES

MAJOR, IMPACTS STRUCTURAL INTEGRITY
Category A



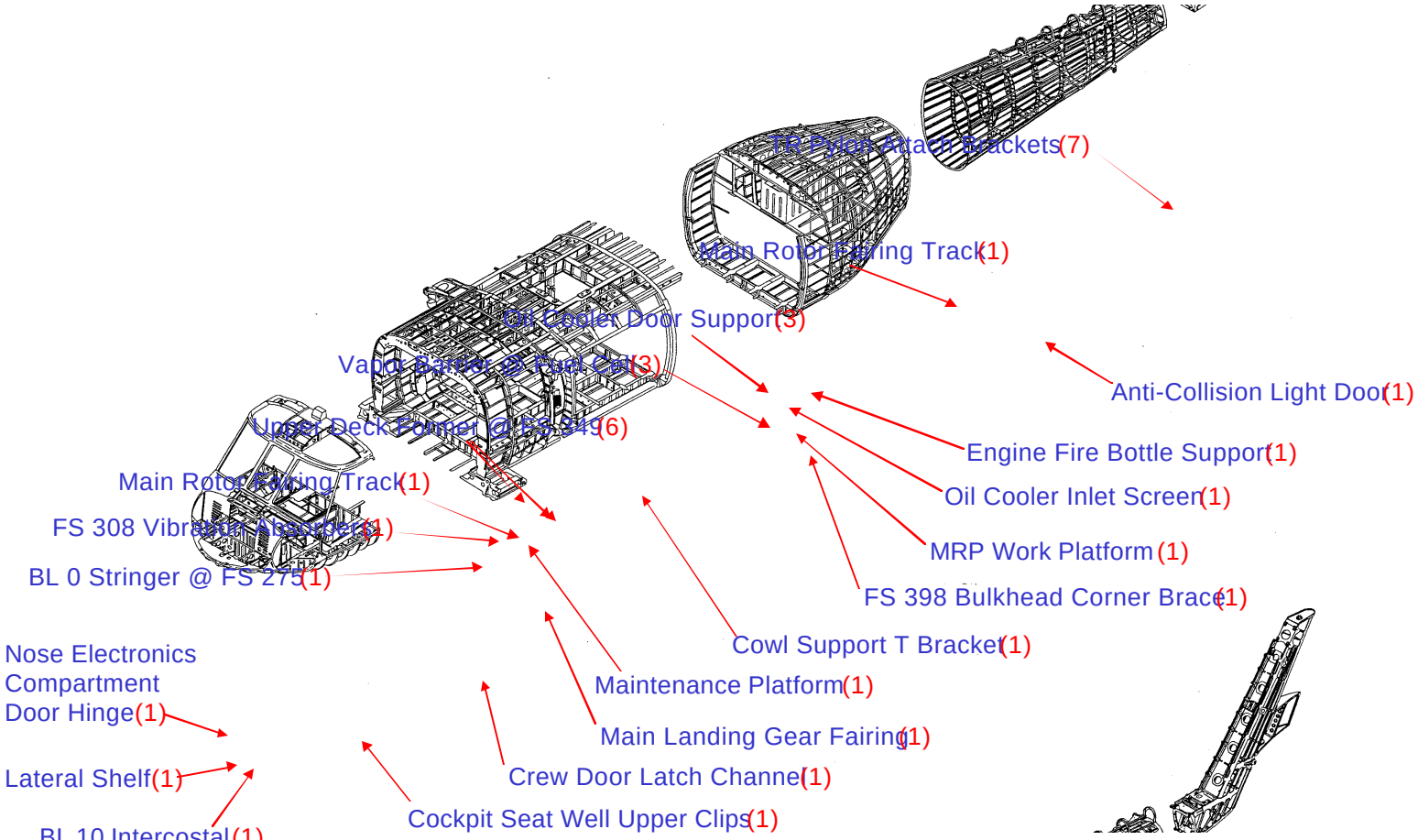
(#) ***Number of Separate Discrepancies at Each Locatio***

SUB-CRITICAL STR DISCREPANCIES
Category B

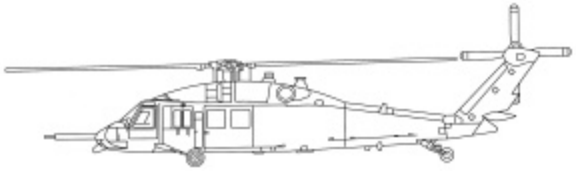


(#) ***Number of Separate Discrepancies at Each Locatior***

MINOR STR INTEGRITY, but MAINT BURDEN
Category C



(#) ***Number of Separate Discrepancies at Each Location***



PARAMETERS MEASURED

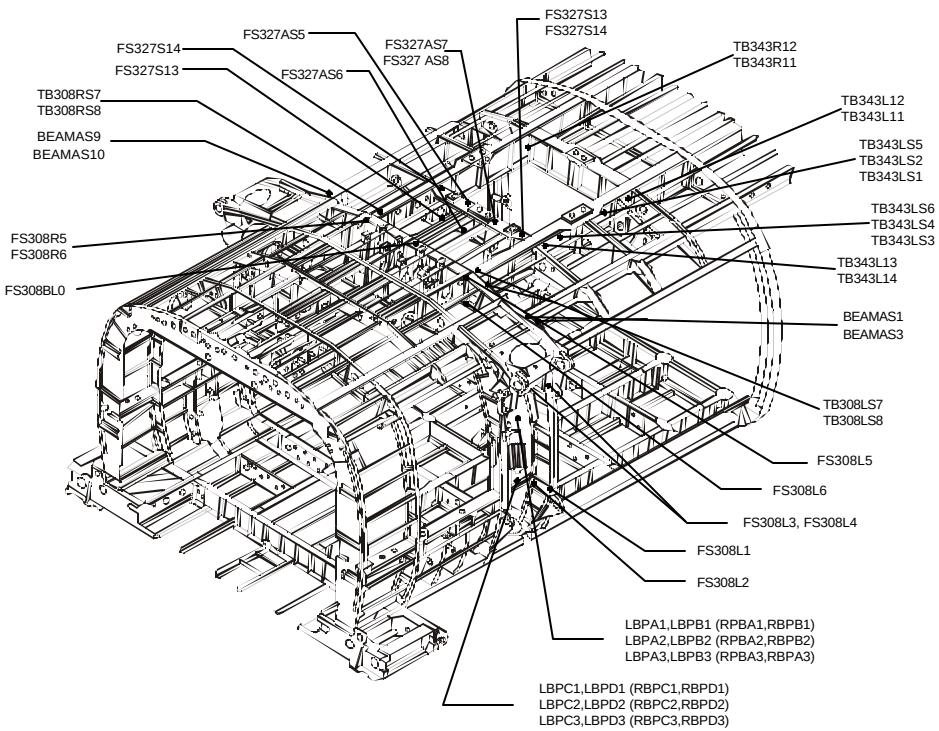
FLT STATE / CONT SYS

Boom Airspeed	Roll Rate
Boom Altitude	Yaw Rate
Boom Rate of Climb	Pitch Acceleration
Angle of Attack Vane	Roll Acceleration
Sideslip Vane	Yaw Acceleration
Boom Outside Air Temp	Normal Load Factor @ CG
No. 1 Engine Torque	Collective Position
No. 2 Engine Torque	Directional Pedal Position
No. 1 Eng T4.5 (TGT)	Longitudinal Position
No. 2 Eng T4.5 (TGT)	Lateral Cyclic Position
Pitch Attitude	Stabilator Position
Roll Attitude	Main Rotor Speed
Heading	Main Rotor Contractor
Pitch Rate	Tail Rotor Contractor

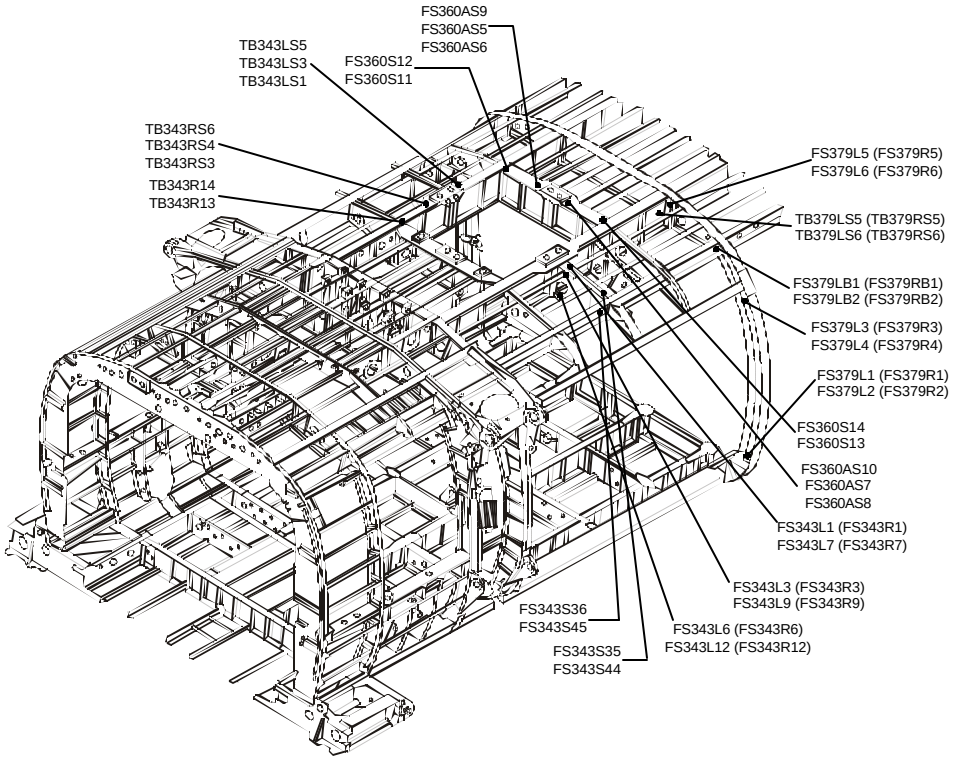
DYN COMPONENTS

PARAMETER	No. Gages	No. Channels
MR Blade Normal Bending	4	1
MR Blade Edgewise Bending	2	1
MR Pushrod Load	2	1
MR Fwd Long Stationary Servo	4	1
MR Lateral Stationary Servo	4	1
MR Aft Long Stationary Servo	4	1
MR Stationary Scissors	4	1
MR Shaft Extender Torque	16	4
MR Shaft Extender Bending	8	2
MR Control Bridge Right Tie Rod	4	1
MR Flapping Angle	Derived	0
TR Stationary Control Load	4	1
TR Blade Spar Flatwise Bending	2	1
TR Torque	12	3
TR Hub Bending Moment	2	1
TOTAL	72	20

CABIN GAGE LOCATIONS



FWD CABIN



AFT CABIN

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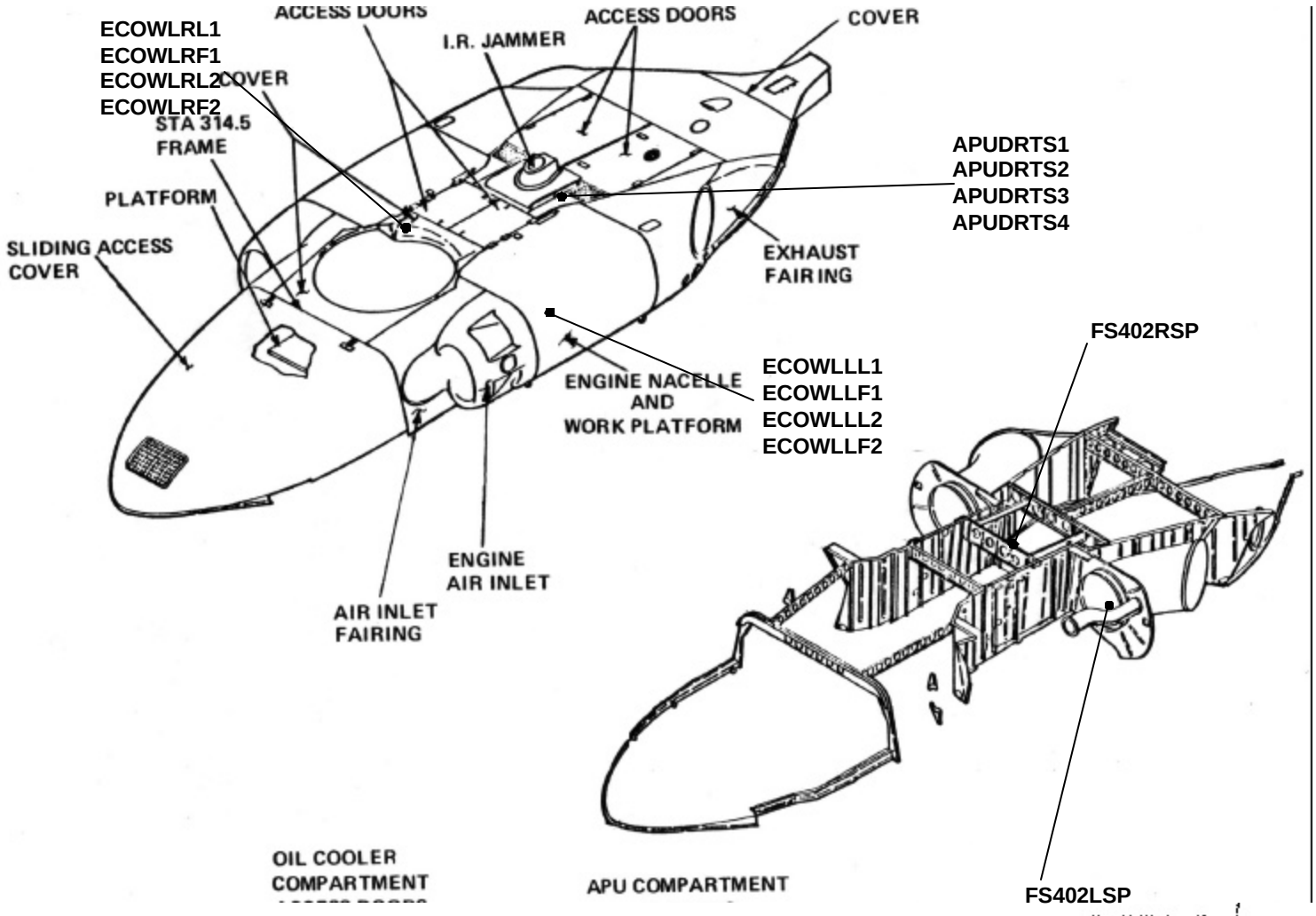
MAIN ROTOR PYLON GAGE LOCATIONS



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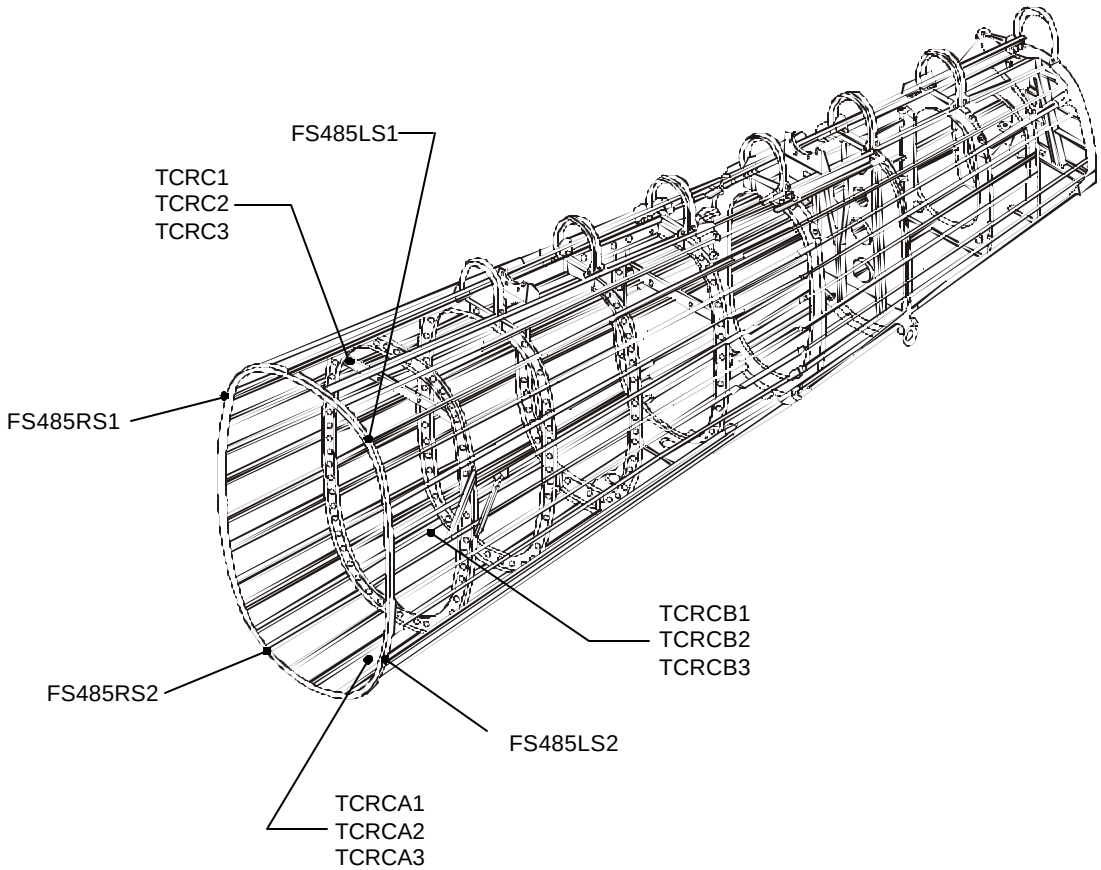
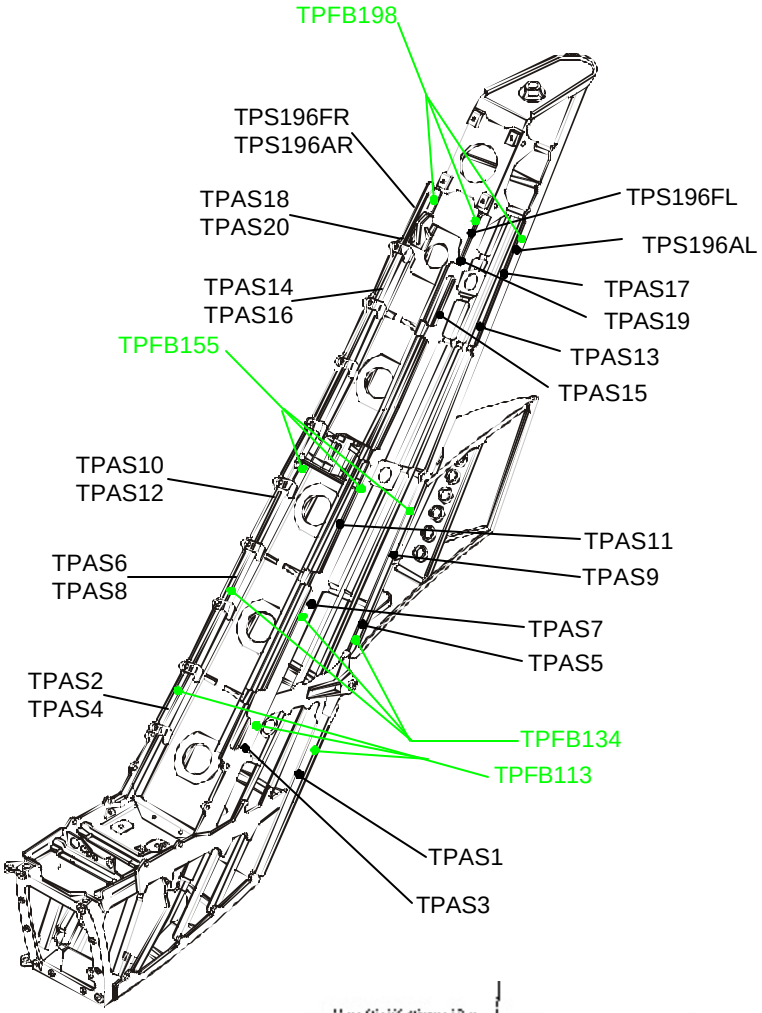
TAIL CONE & PYLON GAGE LOCATIONS





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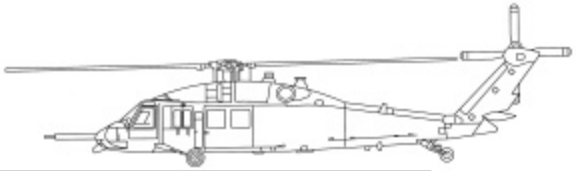
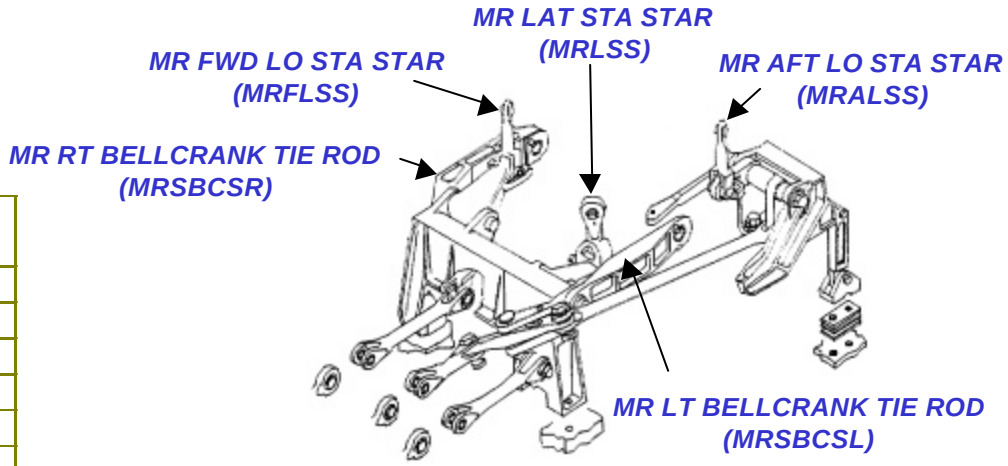
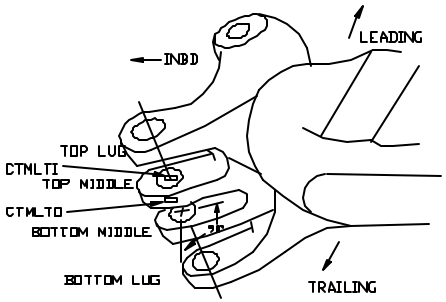


DYNAMIC COMPONENT STRING GAGES

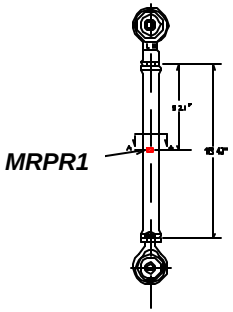
PARAMETER	NUMBER GAGE	NUMBER CHANNEL
MR Blade Normal	4	1
MR Blade Edgewise	2	1
MR Pushrod	2	1
MR Forward Longitudinal	4	
MR Lateral Stationary	4	1
MR Aft Longitudinal Stationary	4	1
MR Stationary	4	1
MR Shaft Extender	16	4
MR Shaft Extender	8	2
MR Control Bridge Right	4	1
MR Flapping	Derive	0
Tail Rotor Stationary Control	4	1
TR Blade Spar Flatwise Bending @ Station 1	2	1
Tail Rotor	12	3
TR Hub Bending	2	1
TOTAL	72	20



MAIN ROTOR SWASHPLATE LINKAGE



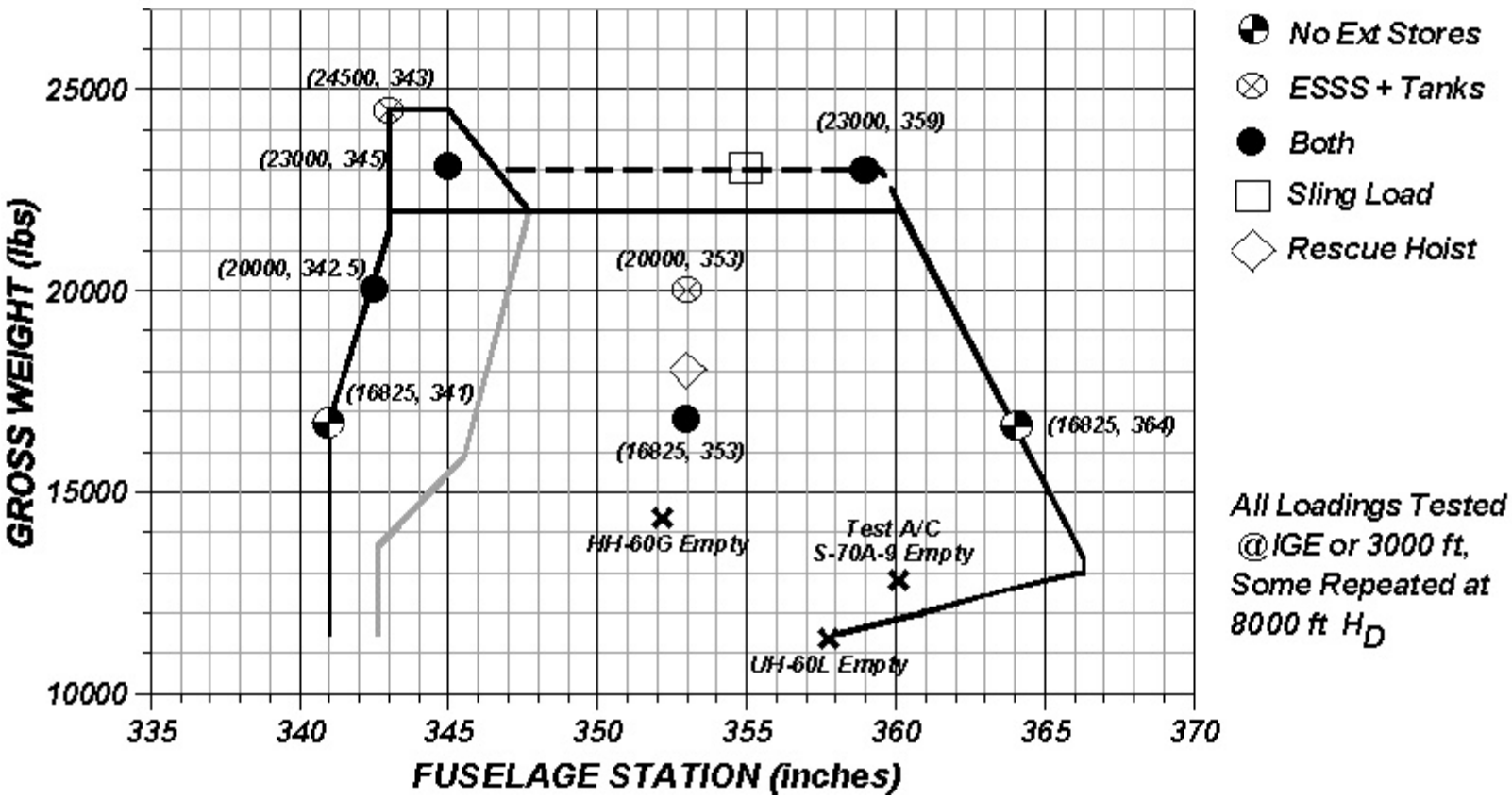
MAIN ROTOR BLADE CUFF

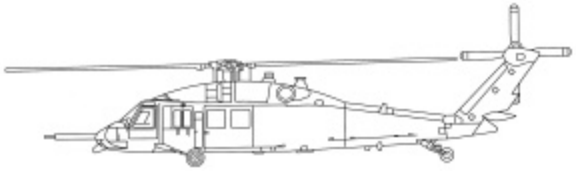


MAIN ROTOR PUSHROD

INSTRUMENTATION RACK & TAIL ROTOR SLIPRING

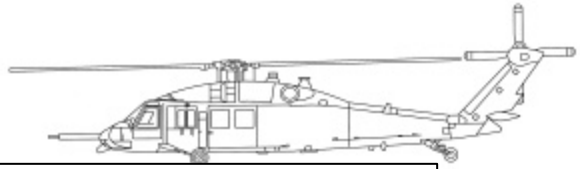
SCOPE OF PROGRAM





FLT STRAIN SURVEY MANEUVER SUMMARY

- Rotor Engagement to 100% Nr, Shutdown
- Ground Taxi Including Taxi Turns
- Hover IGE and OGE
- Air Taxi
- Lt & Rt Hover Turn (15°/sec & 30°/sec)
- Lt & Rt Sideward Flt (Hover to 45 kts, 5kt Intervals)
- Fwd & Rearward Flt (Hover to 45 kts, 5 kt Intervals)
- Dash/Quick Stop, Side Flt from Hover
- Dash/Quick Stop, Fwd Flt from Hover
- Hovering Reversals - Long, Lat, Pedal & Coll
- Takeoff and Climb; V_{broc}, 106% Q
- Level Flt - .4 V_h, .5 V_h, .6 V_h, .7 V_h, .8 V_h, .9 V_h, V_n
- Dives - 1.1 V_h & 1.2 V_h KIAS @ 100% Nr
- Lt & Rt Sideslips; .8 V_h & V_h
- Level Flt - Long, Lat, Pedal & Coll Reversals; .8 V_n KIAS
- Level Flt - .6 V_h & .9 V_h @ 96%, 98%, 99%, 100% & max beep
- Lt & Rt Rolling Pull-outs; .8 V_h & V_h
- Mod & Severe Symmetrical Pull-ups; .8 V_h & V_h
- Pushovers; .8 V_h & V_h
- Terrain Cyclic Pull-up; 40 KIAS
- Terrain Cyclic Push-over; 40 KIAS
- Climbs; V_{mroc}, & V_{mroc} + 15 Kts
- Climbing and Descending Turns; V_{broc}
- Lt & Rt Turns (to 60° AoB); .8 V_n
- Entry & Recovery for above Turns
- Lt & Rt Rapid Decelerating Turns
- Vertical Takeoff
- Collective Pop Up (Jump Takeoff)
- Entry & Recovery Partial Power Descent
- Part Power Descent (1500 fpm); .6 V_h ± 15 KIAS
- Entry Autorotation from .8 V_h & V_{ma}
- Autorotation @ 110% Nr; .8 V_h & V_{ma}
- Auto Long, Lat, Pedal & Coll Revs; .8 V_h & V_{ma}
- Lt & Rt Autorotation Turns; .8 V_h & V_{ma}
- Power Recovery from Autorotation; .8 V_h & V_{ma}
- Approach to Hover (Normal, Rough, Oper)
- Vertical Landing
- Running Takeoff
- Run-on Landing



SPECIAL FLT STRAIN SURVEY OPS

GW 23,000 lbs, mid CG, Hd "1000 ft, 8,000 lbs EXT SLING LOAD

Hover IGE and OGE
Pickup Sling Load
Hover OGE
Vertical Take-off
Lt & Rt Hover Turns (15°/sec)
Lt & Rt Sideward Flt (Hover to 35 kts, 5kt increments)
Rearward Flt (Hover to 35 kts, 5 kt increments)
Hovering Reversals - Long, Lat, Pedal & Coll
Air Taxi (Hover to 50 kts, 10 kt increments)
Normal Takeoff and Climb; 80 kts, 106% Q

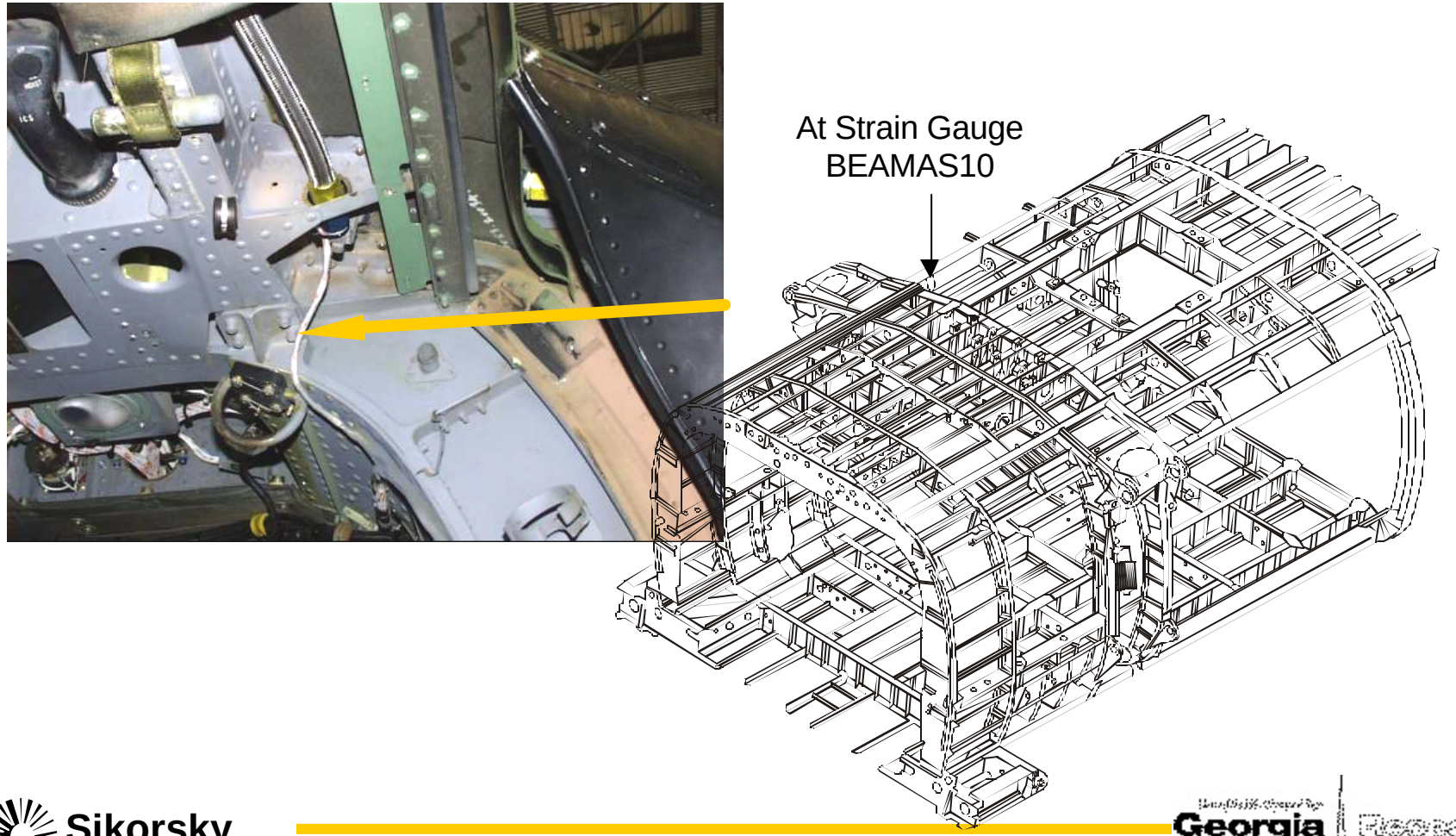
- *Level Flt - 40, 65, 80, 90 KIAS*
- *Level Flt - Long, Lat, Pedal & Coll Reversals; 75 KIAS*
- *Level Flt-80 & 120 KIAS @ 96%, 98%, 99%, 100% & max beep*
- *Climbs; 75 & 90 KIAS*
- *Climbing and Descending Turns; 75 KIAS*
- *Lt & Rt Turns; (to 30° AoB) 85 KIAS*
- *Entry & Recovery for above Turns*
- *Entry & Recovery Partial Power Descent*
- *Part Power Descent (500 fpm); 90 KIAS*
- *Approach to Hover (Normal)*
- *HOGE, Set Load Down*

GW 16,825 lbs, Mid CG, Low Hd (OGE), EXT RESCUE HOIST

Hover, IGE & OGE
Load Pickup
Hover, Hoist Raised
Hover, Hoist Lowered
Hover, Lower Cable Full Length
Air Taxi (Hover to 50 kts, 10 kt Increments)

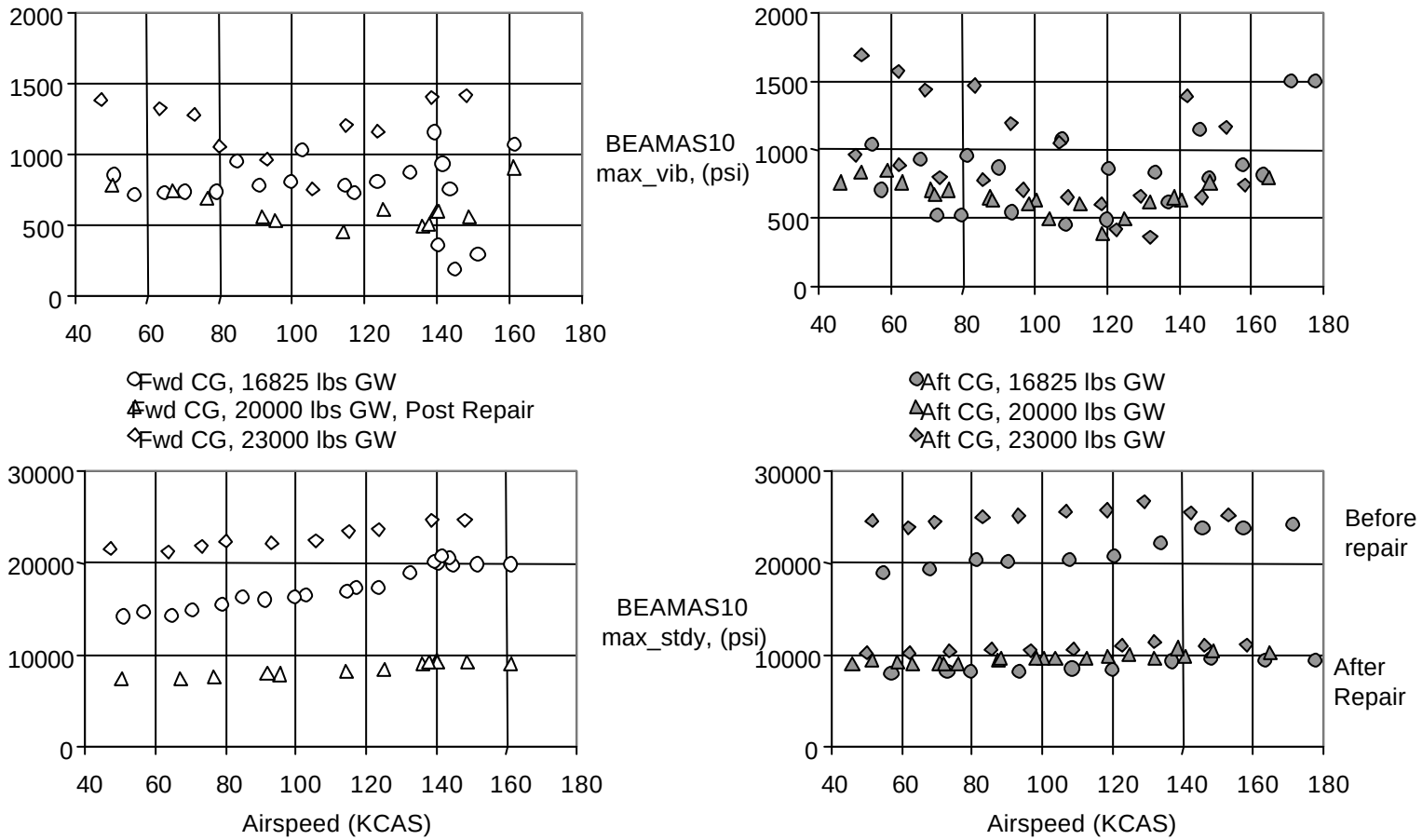
- *Lt & Rt Sideward Flt (Hover to 30 kts, 10kt Increments)*
- *Fwd & Rearward Flt (Hover to 30 kts, 10kt Increments)*
- *Level Flt - (60 to 100 KIAS), 10 kts Increments*
- *Approach to Hover (Normal)*
- *HOGE, Lower Load*
- *HOGE, Set-Down Load*

FS 308 FRAME CRACK LOCATION



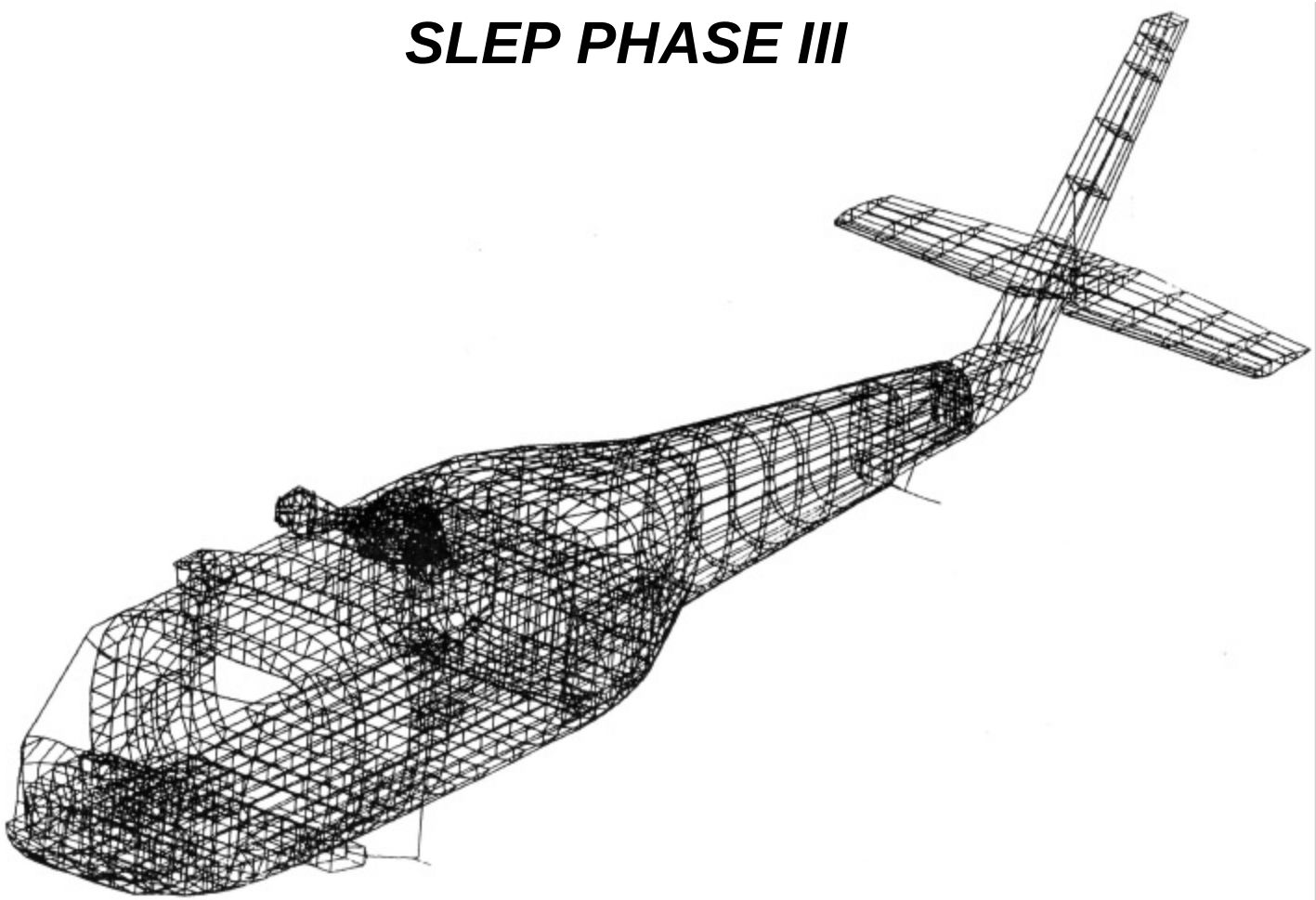
IMPACT of CRACK in FS 308 FRAME

Level Flight 3000 ft Hd, Clean



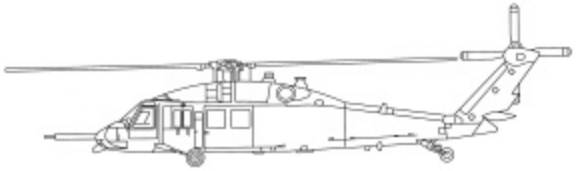
POST TEST ANALYSIS

SLEP PHASE III



LOCAL STRAIN LIFE METHOD

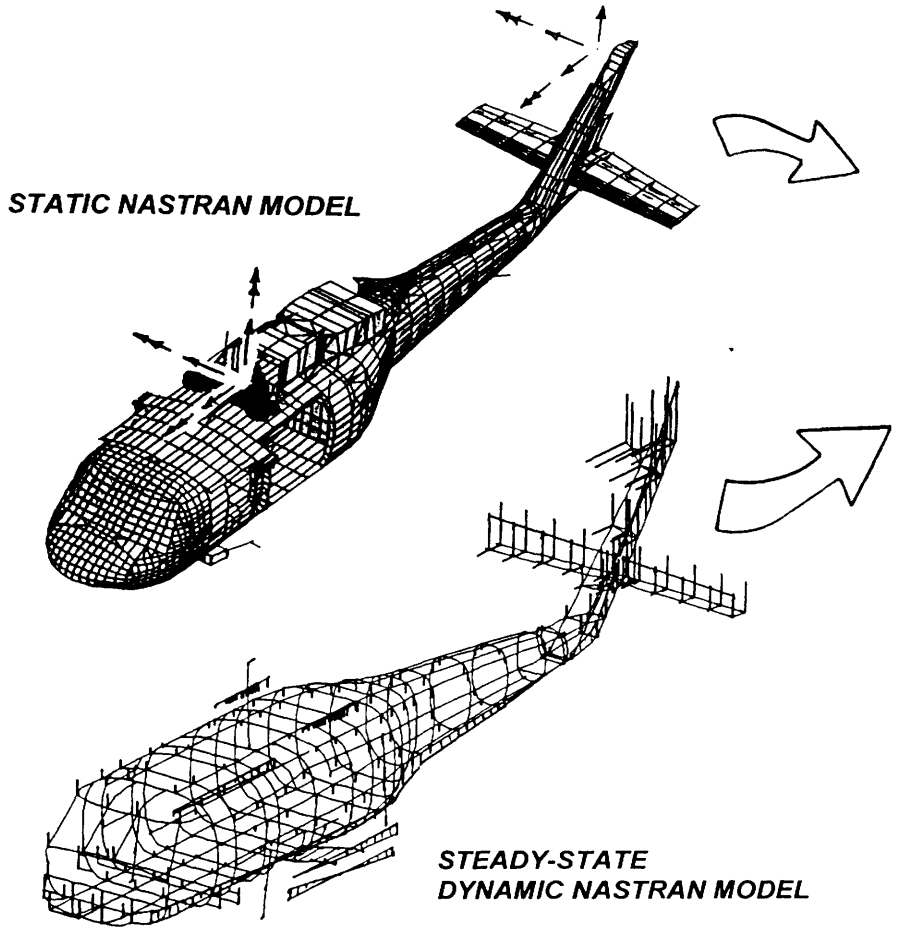
- PREDICTS LIFE for MEMBERS SUBJECTED to SPECTRUM LOADING
- AEROSPACE INDUSTRY STANDARD
- ANALYTICALLY SYNTHESIZES LOCAL STRESS HISTORY from FAR FIELD STRESS HISTORY
- ACCOUNTS for EFFECTS of RESIDUAL STRESSES
  - Life Increased / Decrease due to Overloads
  - Life Enhancement due to Coldworked Holes, Interference Fit Fasteners

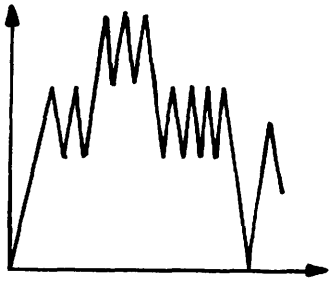


REGRESSION-BASED LOADS CORRELATION

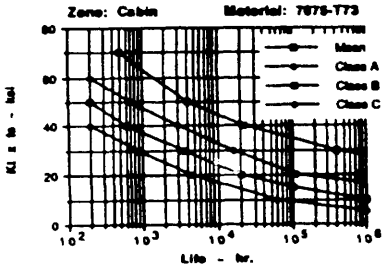
- MINIMIZES DIFFERENCES between PREDICTED and MEASURED STRESSES by ADJUSTING NASTRAN MODEL EXTERNAL LOADS
- LEAST-SQUARES REGRESSION USED to MATCH PREDICTED STEADY and VIBRATORY STRESSES to TEST DATA
- STRESS SPECTRA for BYPASS and BEARING STRESSES can be SYNTHESIZED for each SUBZONE

STRESS SPECTRA & FATIGUE ALLOWABLES GENERATED for ANY LOCATION

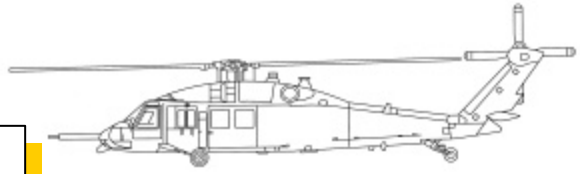




Stress history synthesized by superposition of quasi-static and vibratory stresses



$K_t x f_S$ allowable curve generated using Local Strain Life Method

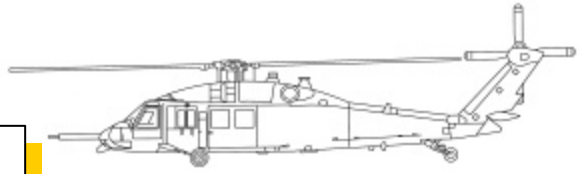


SUMMARY

- ***LARGE QUANTITY of AIRFRAME CRACKS is SIGNIFICANTLY INCREASING OPERATING COST***

- ***HEAVILY INSTR AIRFRAME PROVIDES BASIS for UNDERSTANDING REASONS for CRACKS***
  - ***249 Airframe Strain Gages (217 Channels), 18 Accelerometers***
  - ***80 Dynamic Component Strain Gages (21 Channels)***
  - ***28 Flt State & Control Sys Parameter***

- ***FLT STRAIN MEASUREMENTS at GW / CG EXTREMES & SELECTED MID LOADINGS of FATIGUE SPECTRUM MANEUVERS is MASSIVE but NEEDED DATABASE***



SUMMARY (con't)

- FLT TEST MEASUREMENTS KEY to INCREASING FIDELITY of LOADS (GENHEL) & NASTRAN CODES

- FATIGUE ANALYSIS FOLLOWED by DESIGN of STR ENHANCEMENTS are KEYS to COST EFF SLEP (Flt Test Essential at Beginning)

- JOINT USAF/ADF TEST PROG WORKED WELL (65 flt hrs) (A Cost Avoidance Winner)