Australian Government
Department of Defence
Capability Acquisition and Sustainment Group

S-70A-9 Black Hawk Ageing Aircraft Threats – A SPO Perspective

Army Aviation Systems Program Office

Captain Steve Wardill
S-70A-9 Aero-Mechanical Systems Manager

SCOPE

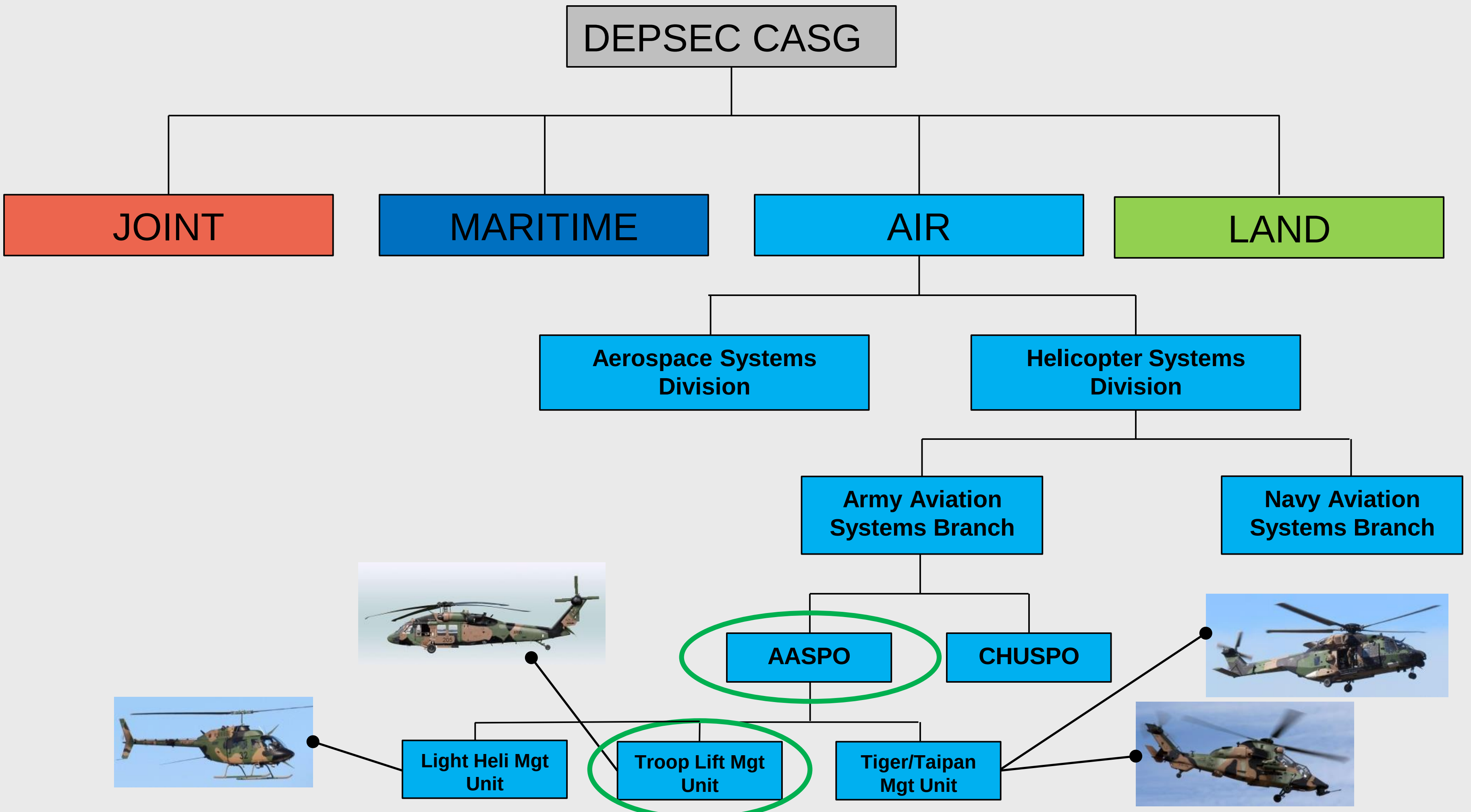
- S-70A-9 Black Hawk overview
- Brief history of S-70A-9 structural integrity management
- S-70A-9 airframe cracking examples
- AASPO considerations for the future
- Case example of an in-house AASPO solution
- Conclusion

REFERENCES

- AASB-SOP-(ENG) 12-0-100 – Enclosure 3 - *S-70A-9 Black Hawk Type Record*
- Boykett, R. (2001), *Airframe Structural Integrity Enhancements for the Black Hawk Helicopter,* Fishermans Bend, DSTO
- Defence Aviation Safety Program (2017), *Helicopter Structural Engineering Familiarisation Course,* (2017), HSEF Course No 01/2017
- *Development of the S-70A-9 Black Hawk AUUS2,* (2011), Melbourne, QinetiQ AeroStructures Pty Ltd
- *Development of the S-70A-9 Condensed AUUS2,* (2011), Melbourne, QinetiQ AeroStructures Pty Ltd
- DGTA-ADF (2012), *Black Hawk Aircraft Structural Integrity Management Plan – Issue 5*
- Dore, C. (2005), *Review of Black Hawk Structural Upgrade Options and Recommendations for the Australian Defence Force,* Fishermans Bend, DSTO
- *HH-60G Airframe Service Life Extension Program Phase 0, Detail Planning,* (1999), Georgia, Georgia Tech Research Institute

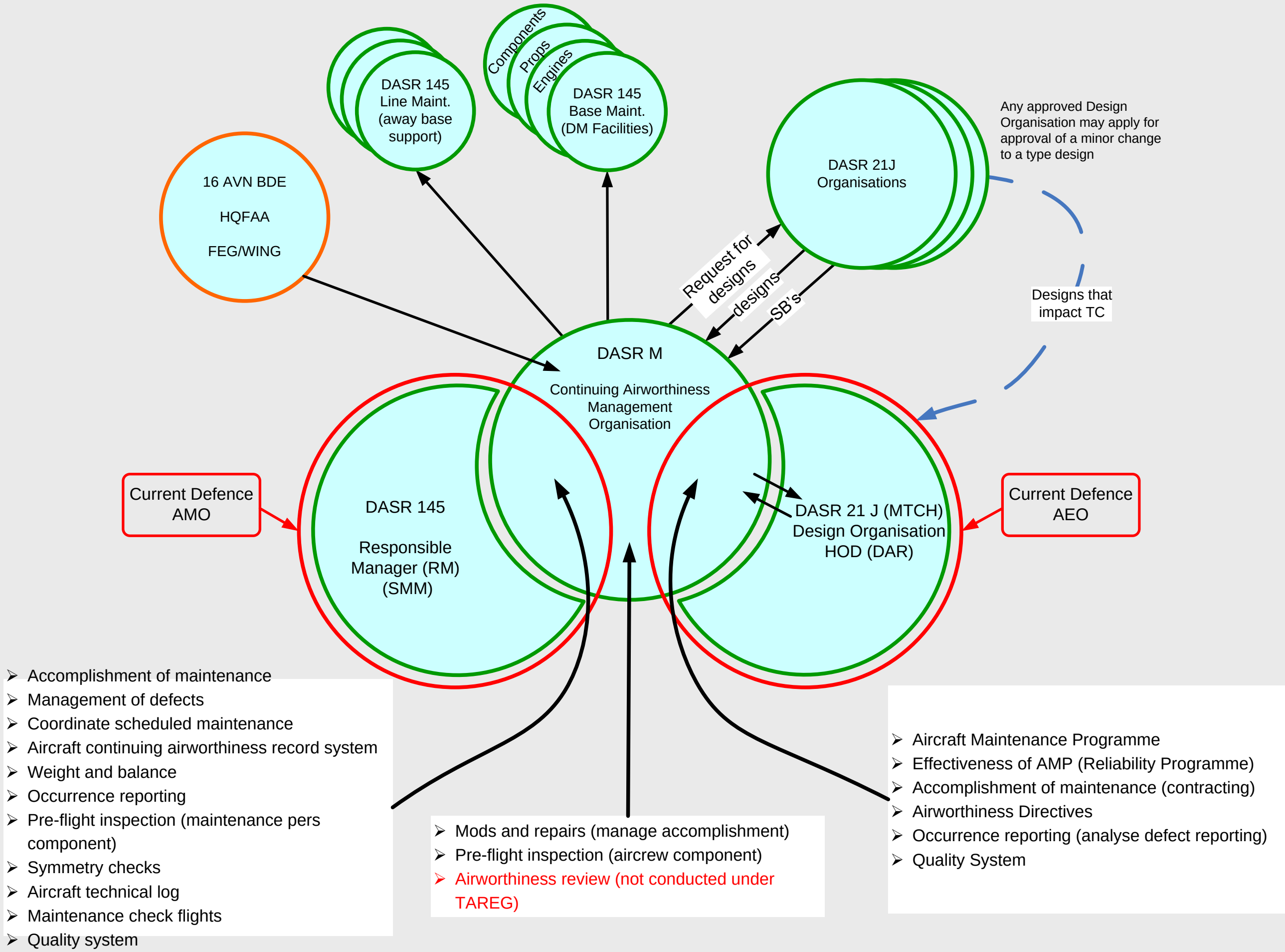
BACKGROUND

Army Aviation Systems Program Office (AASPO)



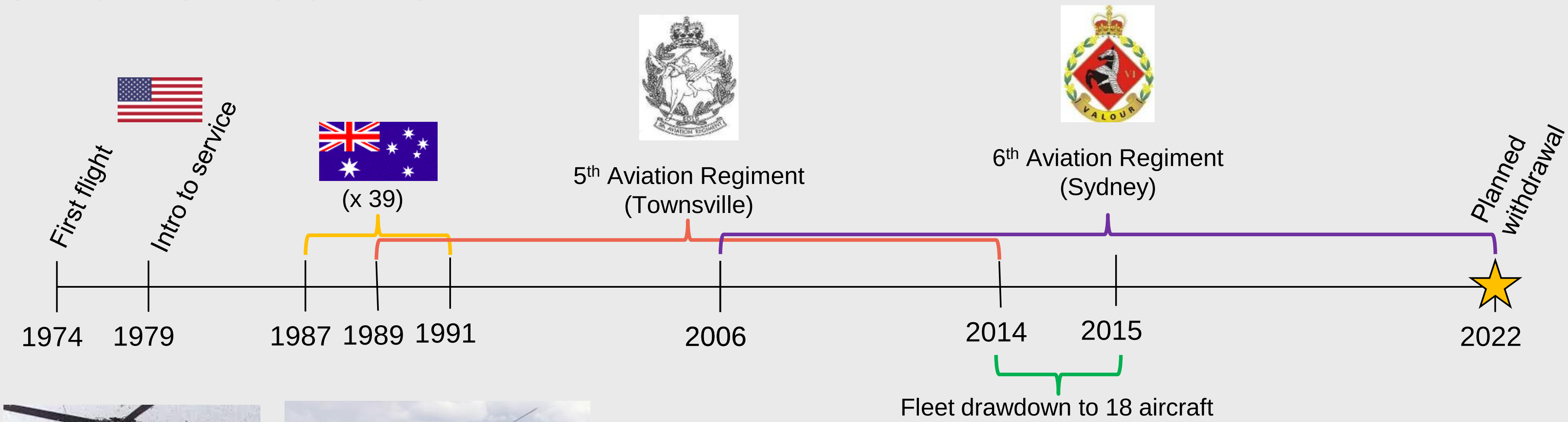
Army Aviation Systems Program Office (AASPO)

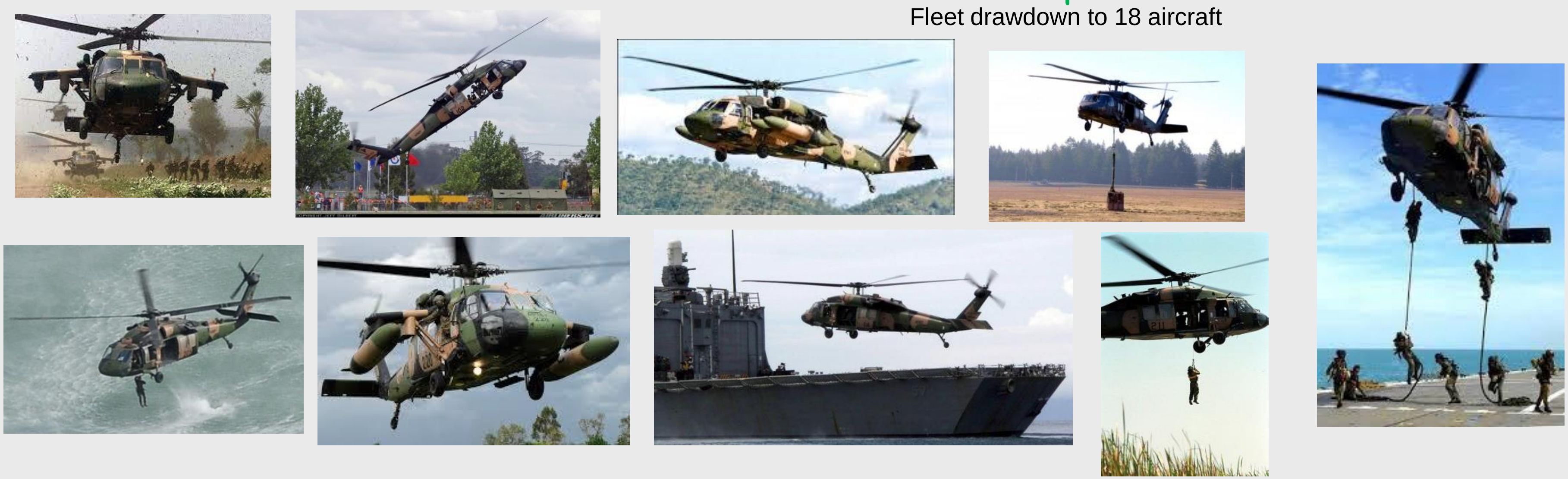
Indicative responsibilities of CAMO, 21J Design and 145 AMO against TAREG AEO and AMO



BACKGROUND

S-70A-9 Black Hawk





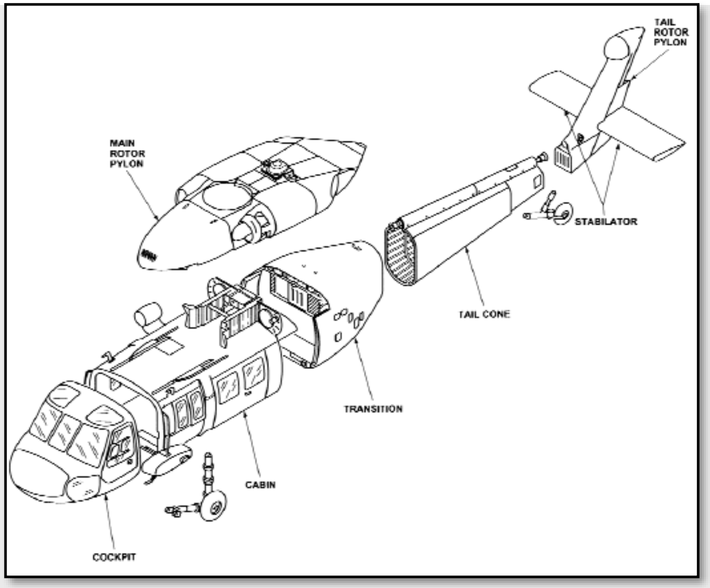
BACKGROUND

S-70A-9 Black Hawk

Design

Specifications/Standards:

- **MIL-S-8698**
  - Structural Design Requirements, Helicopters
- **MIL-A-008860A**
  - Airplane Strength and Rigidity Reliability Requirements, Repeated Loads and Fatigue
- **SER-50586**
  - Fatigue Properties and Analysis
- **MIL-T-5955C**
  - Transmission Systems
- **SES-701051**
  - Finishings and Coatings
- **MIL-008870A**
  - Airplane Strength & Rigidity (Aeroelastic Instability)
- **MIL-A-008860A**
  - Airplane Strength and Rigidity (Primary Structure)



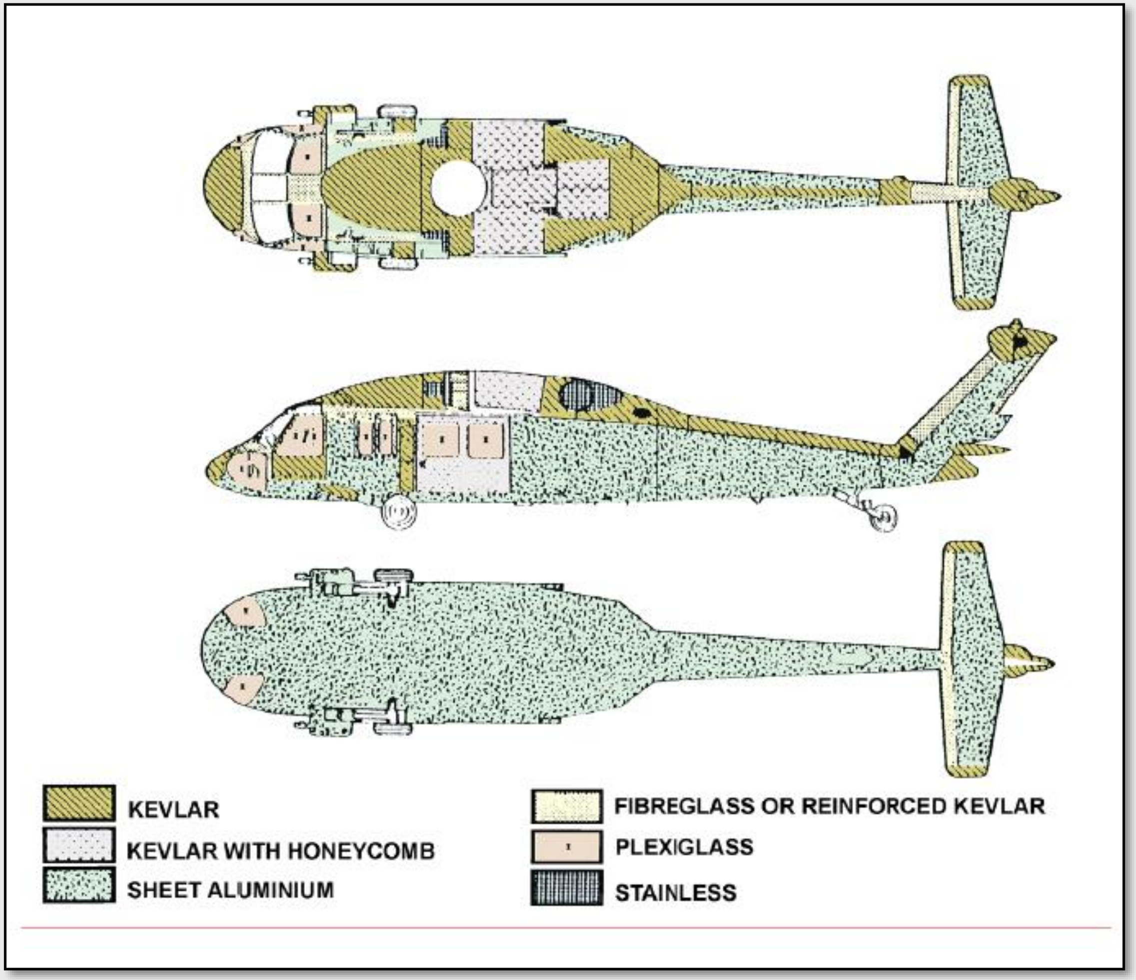
Flight Essential Component	Projectile	Striking Velocity
Control rods (Primary Servo to Main Rotor Blades)	12.7 mm AP	1600 ft/sec
Main Rotor Swash Plate Assembly	12.7 mm AP	1600 ft/sec
Main Rotor Shaft	23 mm AP or 23 mm HE	1600 ft/sec
Main Rotor Hub and Elastomeric Bearing Assembly	23 mm AP	1600 ft/sec or 23 mm HE
Main Rotor Blades	23 mm AP 23 mm HE	1600 ft/sec at 1600 ft/sec for at least 90 percent of lower hemisphere type impacts
Tail Rotor Drive Shaft (tail cone)	12.7 mm AP	1600 ft/sec
Tail Rotor Drive Shaft (Pylon)	23 mm AP	2600 ft/sec
Tail Rotor Hub	12.7 mm AP	1600 ft/sec
Tail Rotor Blade (Flatwise)	23 mm AP	2600 ft/sec

S-70A-9 Black Hawk

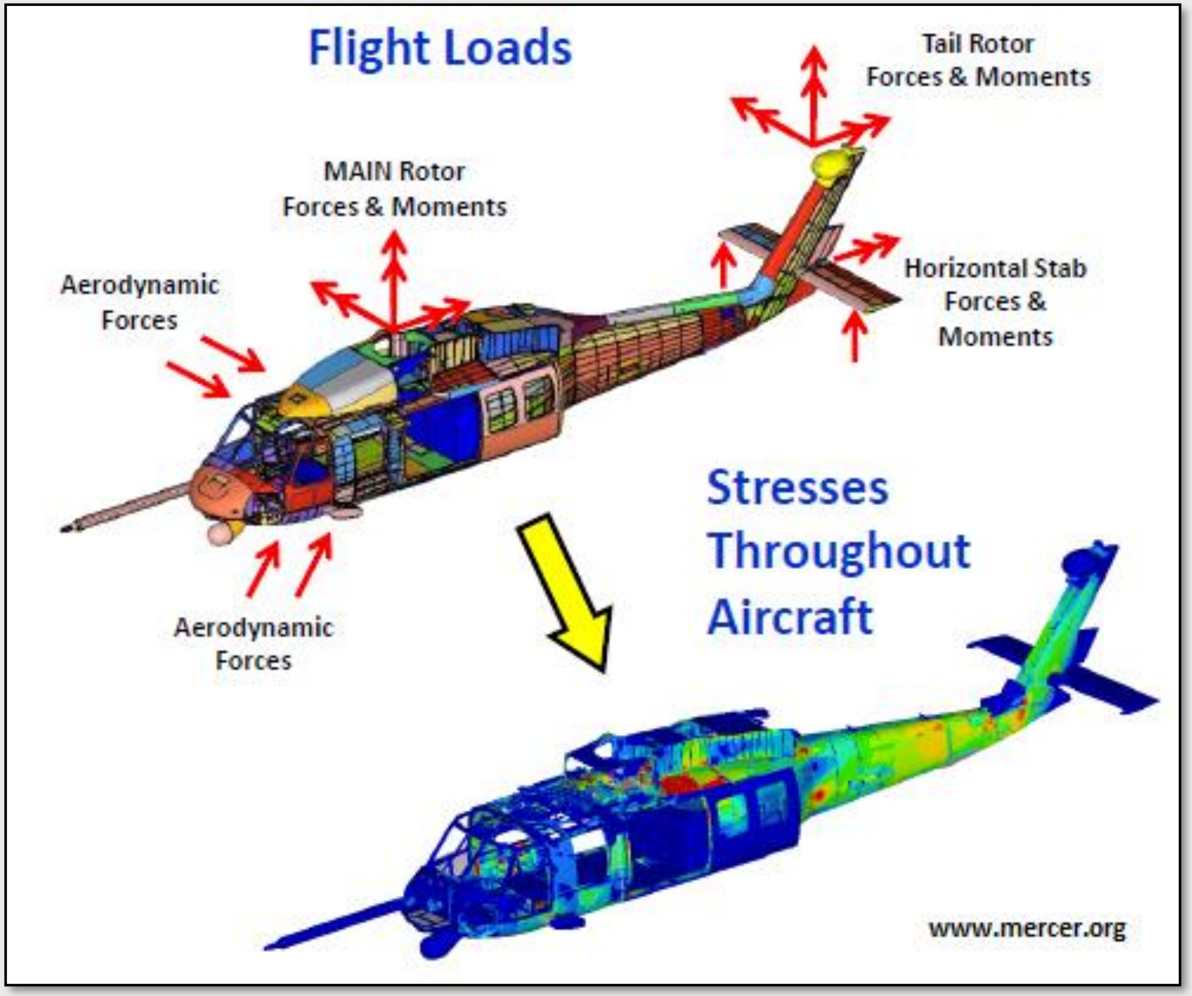
Design

Materials:

- Sheet and extrusion:
  - 7075-T6
  - 2024-T4
- Forged/machined fittings:
  - 7075-T6511
  - 2024-T6511



S-70A-9 Black Hawk



S-70A-9 Black Hawk

Unique ADF Characteristics

- Improved durability gearbox (Seahawk main transmission)
- Rotor brake
- Automatic Flight Control System
- Armour protection
- Hydraulic Rescue Hoist
- Wire strike protection system
- ESSS provisions
- Folding stabilator
- Hover IR suppressors
- Unique avionics configuration
- Counter-measure provisions

DESIGN USAGE SPECTRUM

Australian Unique Usage Spectrum (AUUS)

- At purchase, S-70A-9 CRTs based on UH-60A design usage spectrum
- In 1992 Sikorsky contracted to create unique ADF spectrum
- Data obtained through:
  - Mission monitoring forms
  - Long form questionnaire
  - Witnessing
- Sikorsky determined that S-70A-9 spectrum more severe than UH-60A spectrum
- Impact study recommended revised CRTs (RRTs) for five components:

Component	UH-60A CRT (Flt Hr)	S-70A-9 RRT (Flt Hr)
Main Support Bridge	1800	910
Main Rotor Cuff	2400	980
Main Rotor Hub	5400	2600
Rotating Swashplate	11000	6400
Tail Rotor Output Shaft	5100	3300

- ADF subsequently introduced a paper based usage monitoring system (EE360 forms)

DESIGN USAGE SPECTRUM

AUUS2

- Subsequent comparisons of EE360 data to AUUS suggested that revised S-70A-9 CRTs may be overly conservative
- Black Hawk CRT Project raised. QinetiQ tasked with developing modified AUUS (AUUS2), based on 5 years of EE360 data
- AUUS2 approved for use in 2010.

Condensed AUUS2

- Scope of original AUUS work performed by Sikorsky limited to CRT analysis of only 12 components – flight loads for remaining critical structures were not available
- In order to expand component CRT analysis QinetiQ tasked with manipulating AUUS2 to match UH-60A design usage spectrum – known as Condensed AUUS2.

Flight Manoeuvre Recognition Software

- Introduced in 2015
- Interrogates FDR data
- Has so far strengthened confidence in CRTs derived from AUUS2.

AIRFRAME STRUCTURAL MANAGEMENT

Significant H-60 Airframe Studies:

HH-60G Airframe Structural Integrity Enhancements (1995)

- Georgia Tech Research Institute (GTRI) commissioned to determine airframe structural integrity enhancements for USAF HH-60G Pave Hawk aircraft associated with addition of mission equipment to aircraft
- 17 fatigue ‘hot spots’ identified from review of in-service history.

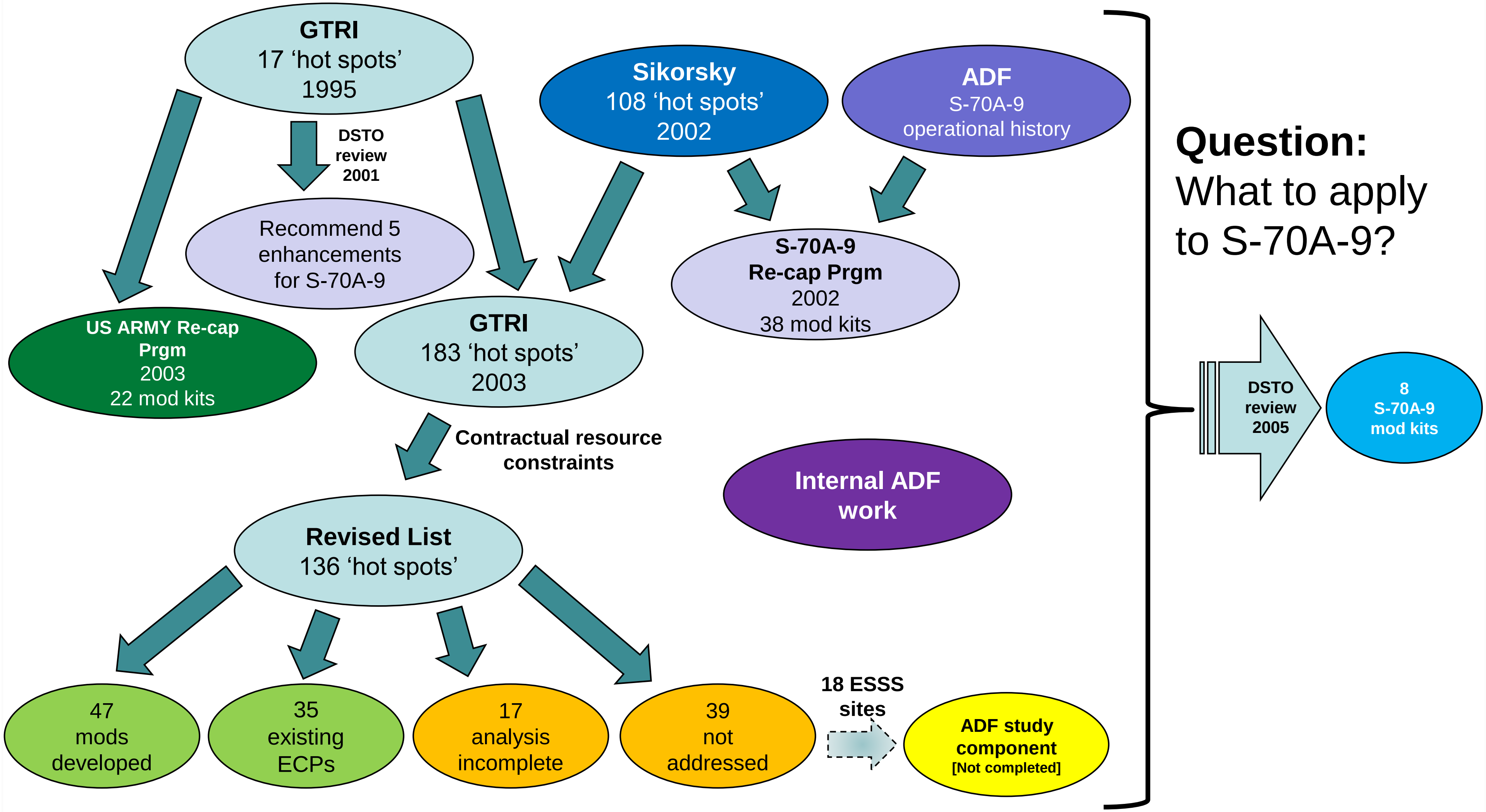
Sikorsky Identification of Critical Airframe Fatigue Sites (2002)

- Advanced Structural Technology Inc. commissioned by Sikorsky to identify 100 most critical airframe fatigue sites, for further analysis
- 108 cracking ‘hot spots’ identified.

HH-60G Service Life Extension Program (2003)

- USAF requirement to extend HH-60G Pave Hawk life to 2015 (20 000 flt hrs)
- GTRI reviewed 2600 fatigue occurrences across 650 USAF and US ARMY aircraft
- 183 fatigue ‘hot spots’ identified.
  - 96 Category A (critical/major problems having direct impact on the airframe structural integrity and safety of flight)

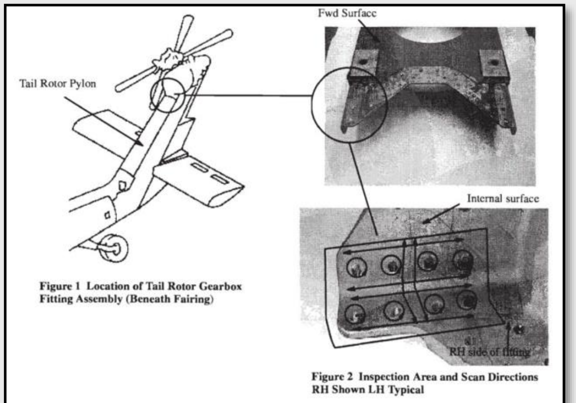
AIRFRAME STRUCTURAL MANAGEMENT



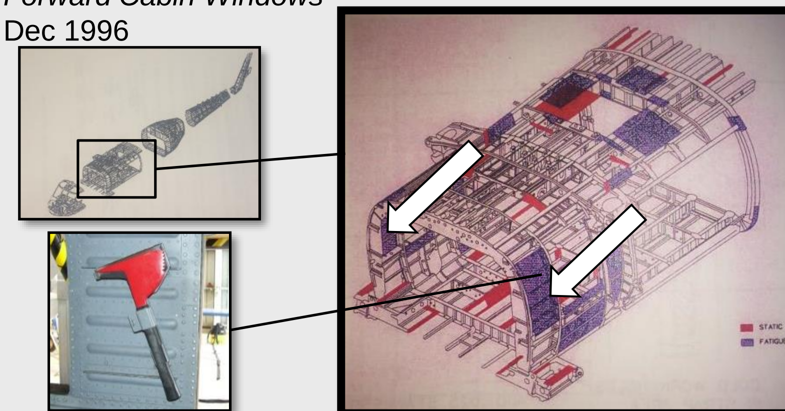
Question:
What to apply to S-70A-9?

STRUCUTRAL MODIFICATIONS

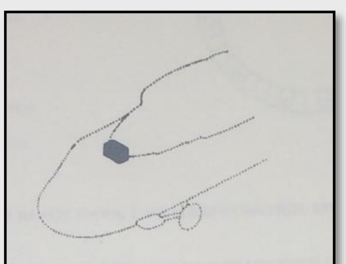
Mod -184
Tail Pylon Assembly Structural Reinforcement and Fatigue Enhancement
Dec 1997

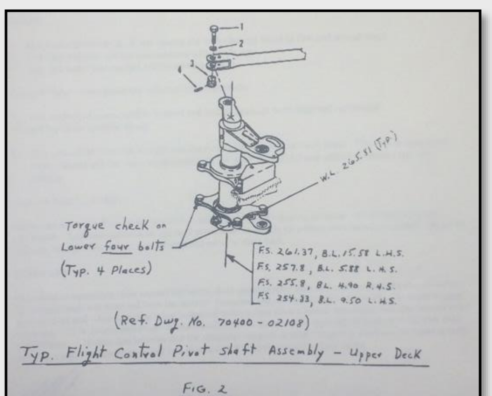


Mod -185
Installation of Inner and Outer Structural Reinforcement Around Forward Cabin Windows
Dec 1996

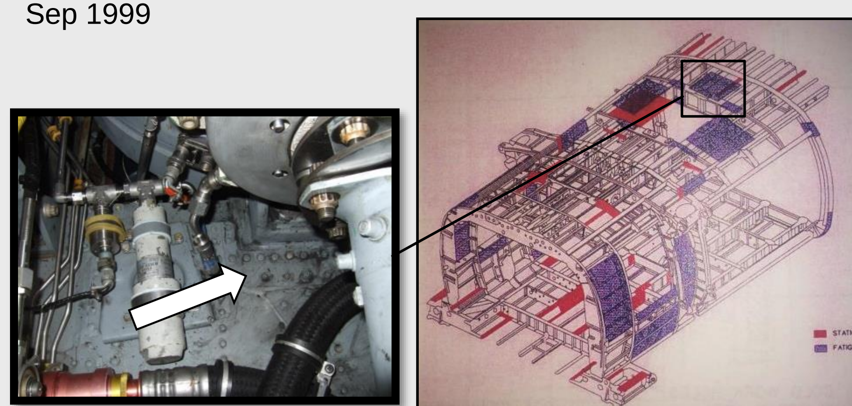


Mod -190
Yaw Torque Shaft Support Structure Reinforcement
Dec 1997



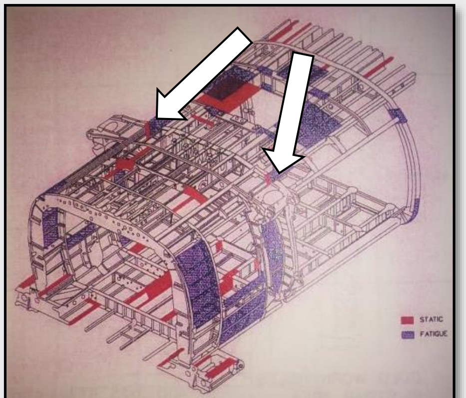


Mod -208
Installation of Support Doubler to Aft Transmission Beam
Sep 1999

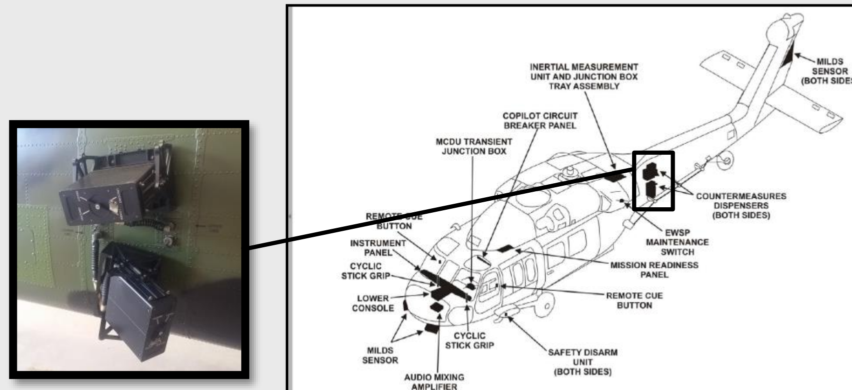


STRUCUTRAL MODIFICATIONS

Mod -221
Installation of Structural Reinforcement in Upper Cabin
Aug 2003

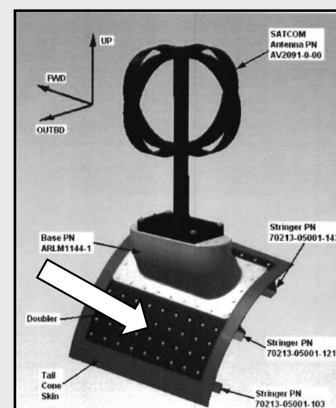


Mod -243
Installation of Countermeasures Dispenser System
May 2010



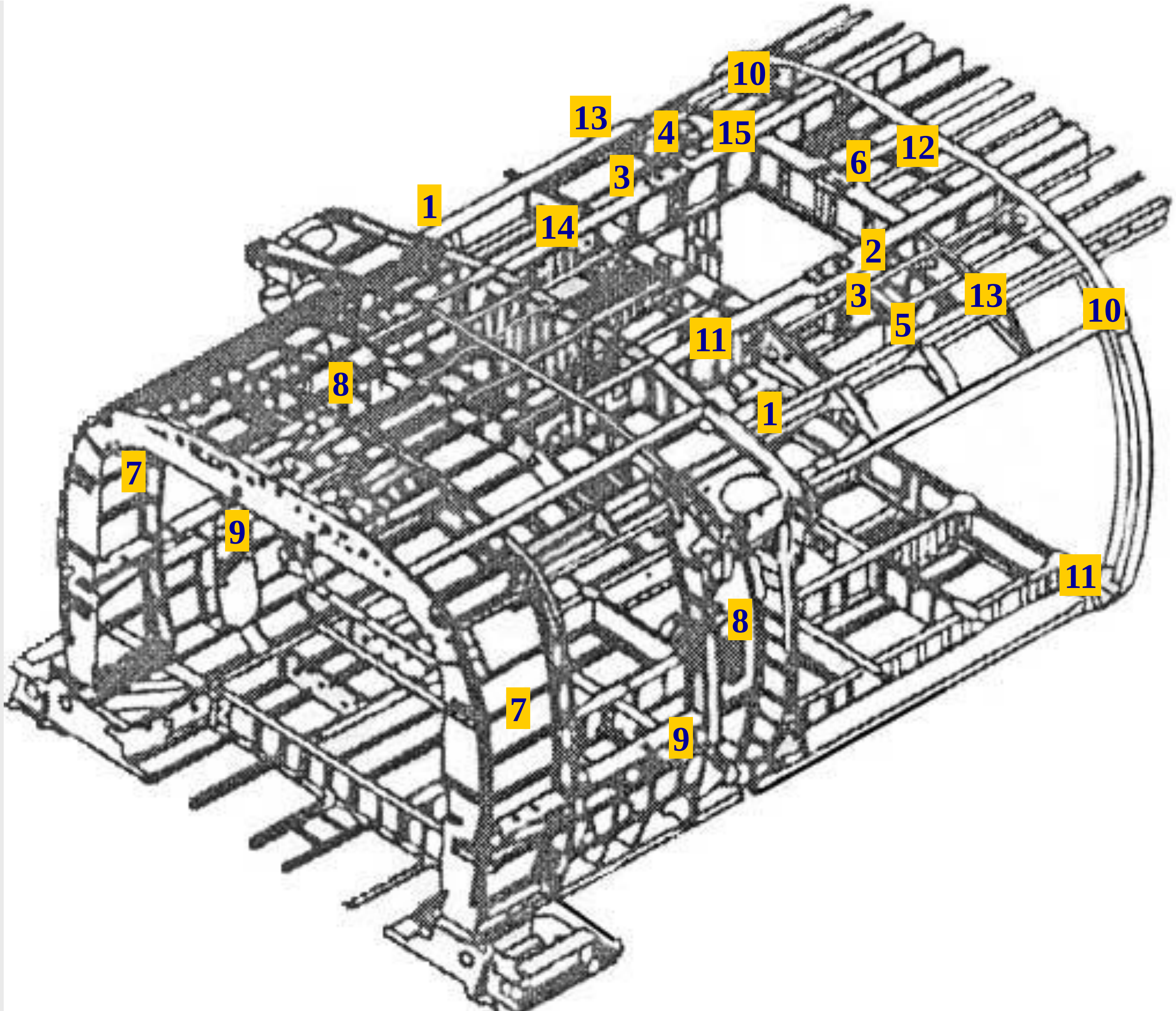
Mod -248
Installation of SATCOM and Line of Sight Antennas
Dec 2012

Mod -259
Installation of SATCOM Antenna Base Reinforcing Doubler
Oct 2013



H-60 AIRFRAME HOT SPOTS

1. FS 308, BL 34.5 Beam Splice
2. LH BL 16.5 Beam aft of FS 343
3. L&R Beam Tabs @ FS 343
4. RH Upper Roof Skin @ FS 343
5. LH Upper Roof Skin @ FS 343
6. FS 360 Frame Tang
7. Side Cabin Skins @ FS 247-FS 262
8. Beaded Panel



9. Cabin Inner Skin @ FS 295
10. FS 379 Frame WL 255 Splice
11. FS 379 Frame WL 206 Splice
12. FS 360 Upper Roof Skin
13. Upper Roof Skin @ FS 349, BL20
14. Rescue Hoist Shear Deck @ FS 327, BL16.5
15. Rescue Hoist Shear Deck @ FS 360, BL16.5

S-70A-9 AIRFRAME HOT SPOTS

1. FS 308, BL 34.5 Beam Splice

2. LH BL 16.5 Beam aft of FS 343

3. L&R Beam Tabs @ FS 343

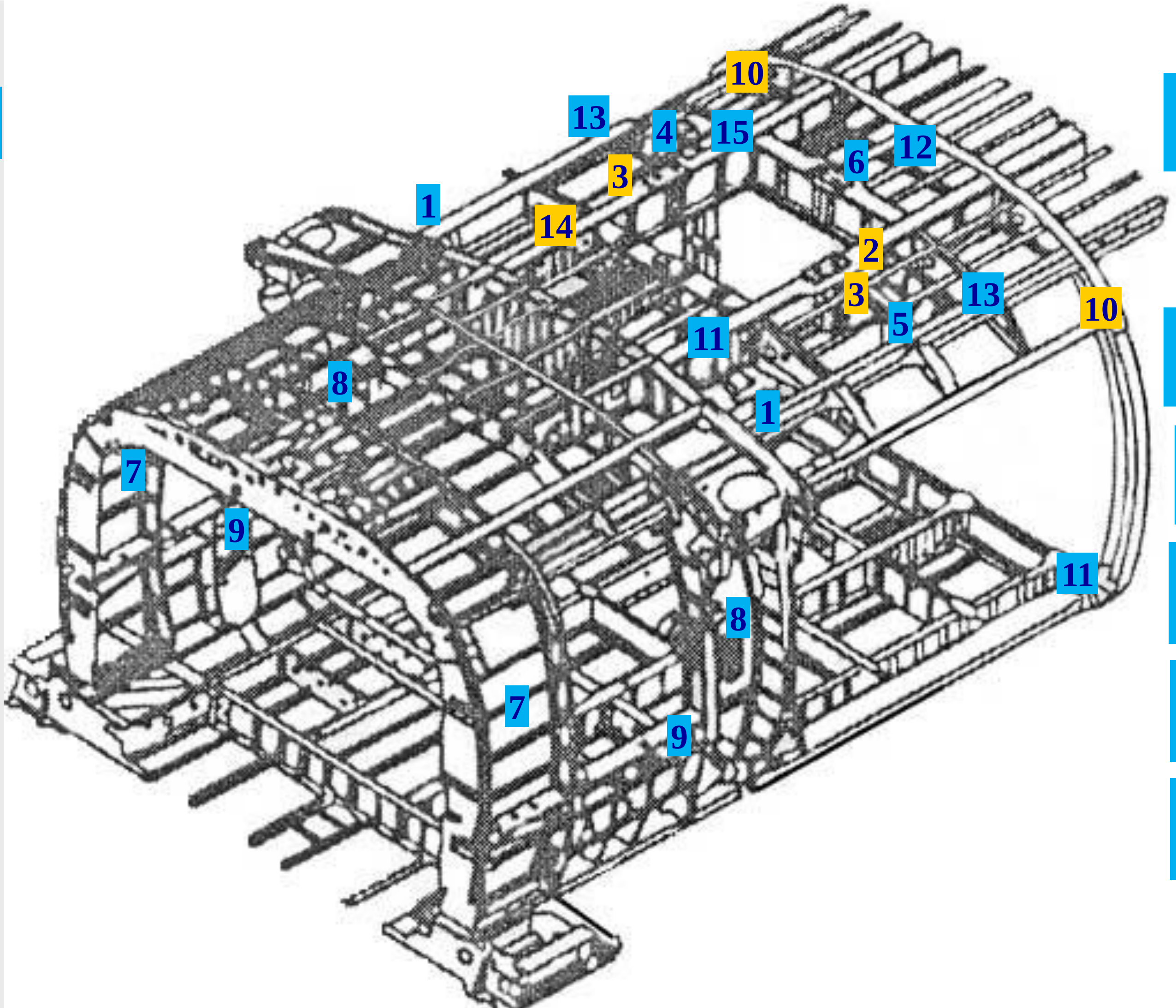
4. RH Upper Roof Skin @ FS 343

5. LH Upper Roof Skin @ FS 343 (QTY 19)

6. FS 360 Frame Tang (QTY 18)

7. Side Cabin Skins @ FS 247-FS 262 (QTY 20)

8. Beaded Panel



9. Cabin Inner Skin @ FS 295 (QTY 4)

10. FS 379 Frame WL 255 Splice

11. FS 379 Frame WL 206 Splice (QTY 5)

12. FS 360 Upper Roof Skin (QTY 14)

13. Upper Roof Skin @ FS 349, BL20 (QTY 12)

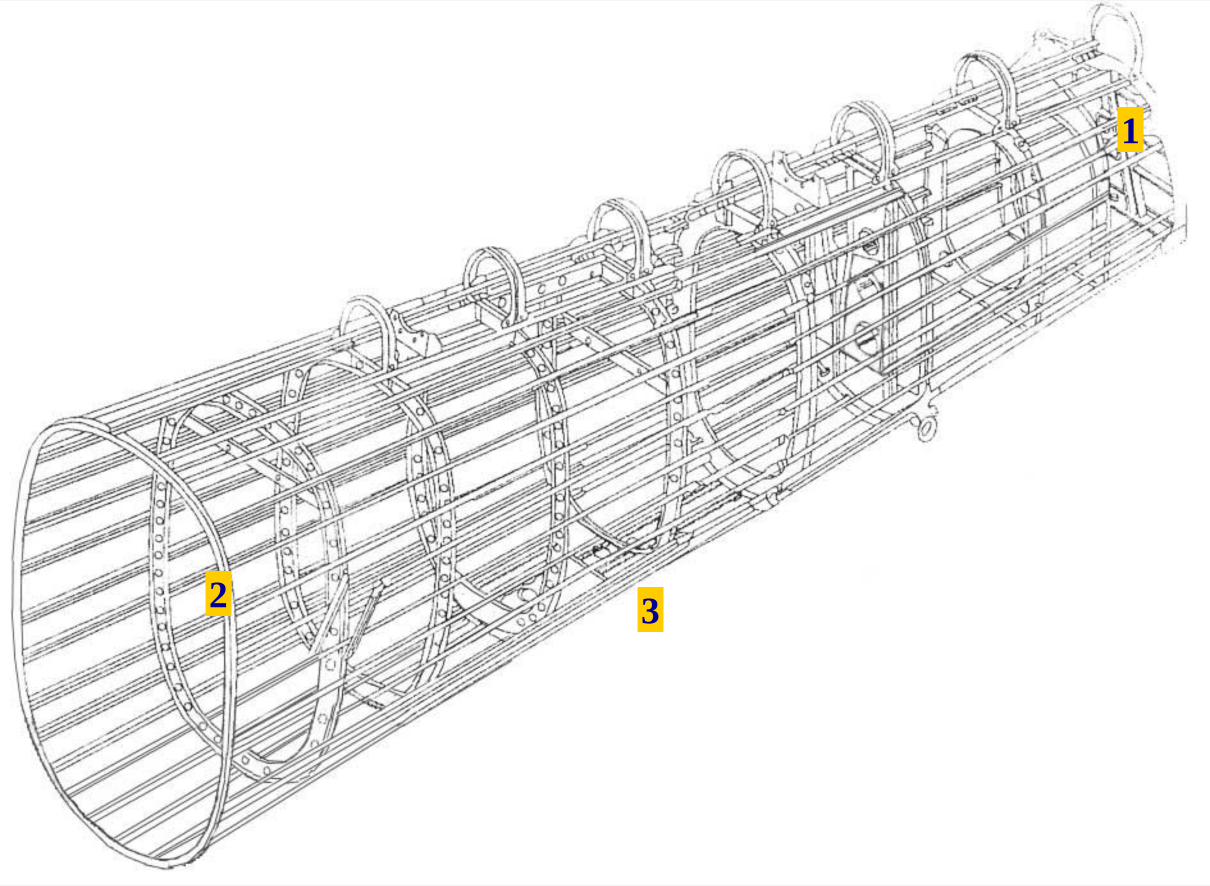
14. Rescue Hoist Shear Deck @ FS 327, BL16.5 (QTY 5)

15. Rescue Hoist Shear Deck @ FS 360, BL16.5 (QTY 4)

S-70A-9 AIRFRAME HOT SPOTS

1. Longeron Splice Cantered Bulkhead FS 647

2. Tension Fittings @ Splice to Transition Section FS 485

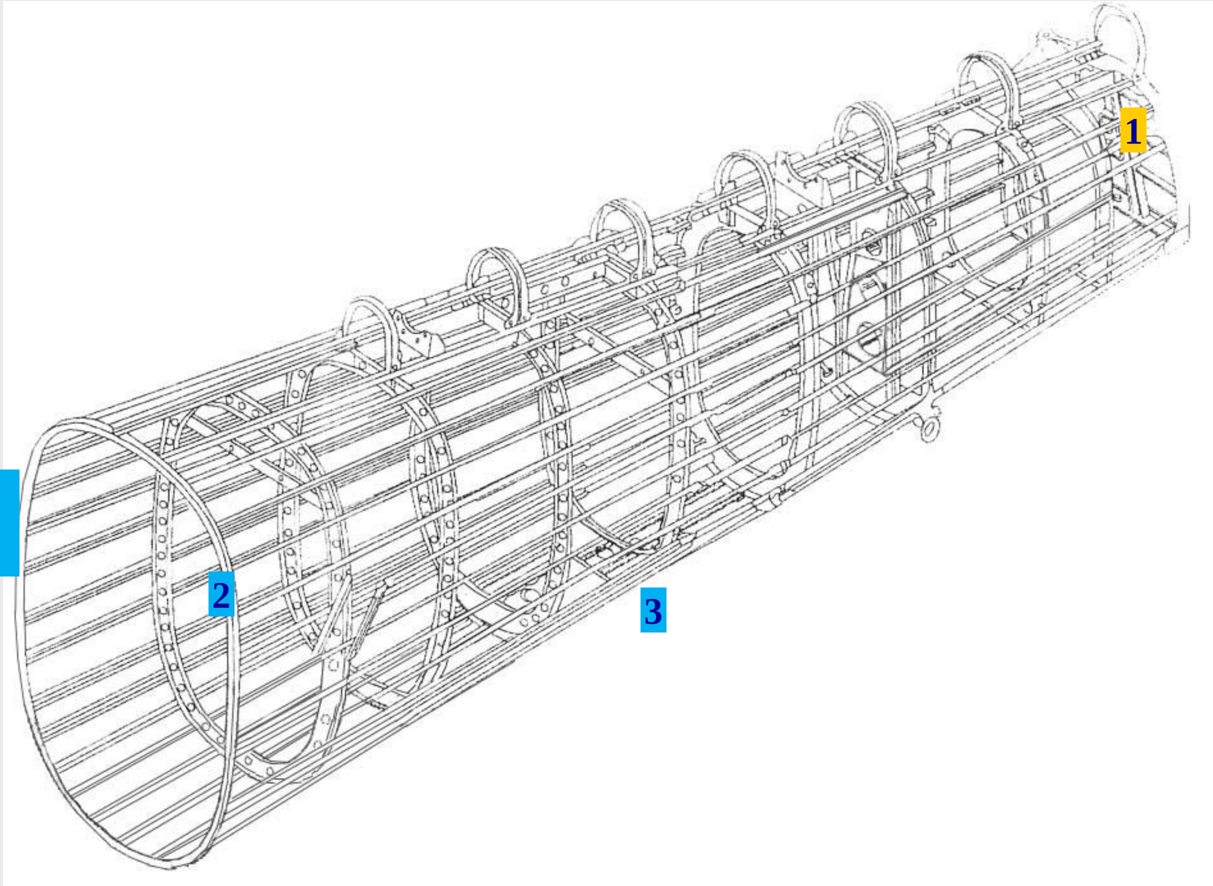


3. Tail Cone Skins

S-70A-9 AIRFRAME HOT SPOTS

1. Longeron Splice
Cantered Bulkhead
FS 647

2. Tension Fittings @ Splice to
Transition Section FS 485
(QTY 13)

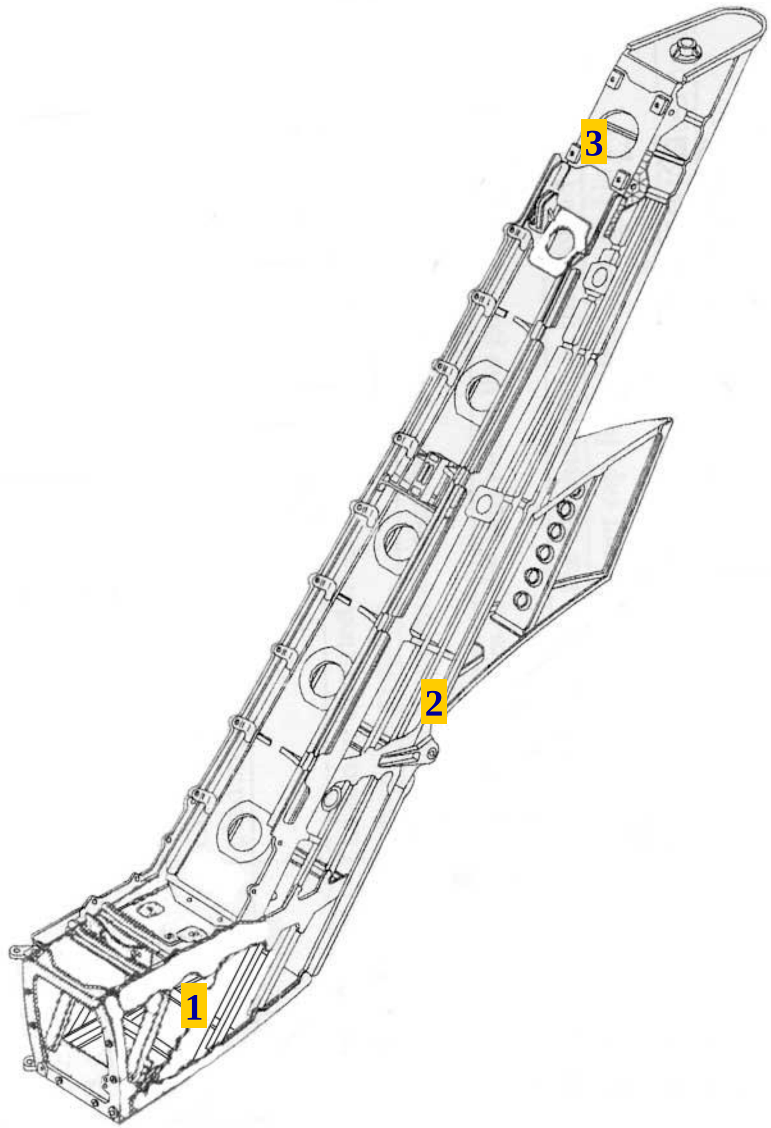


3. Tail Cone Skins

S-70A-9 AIRFRAME HOT SPOTS

1. Fwd Spar Splice

2. Aft Spar Splice @ Horizontal Stab

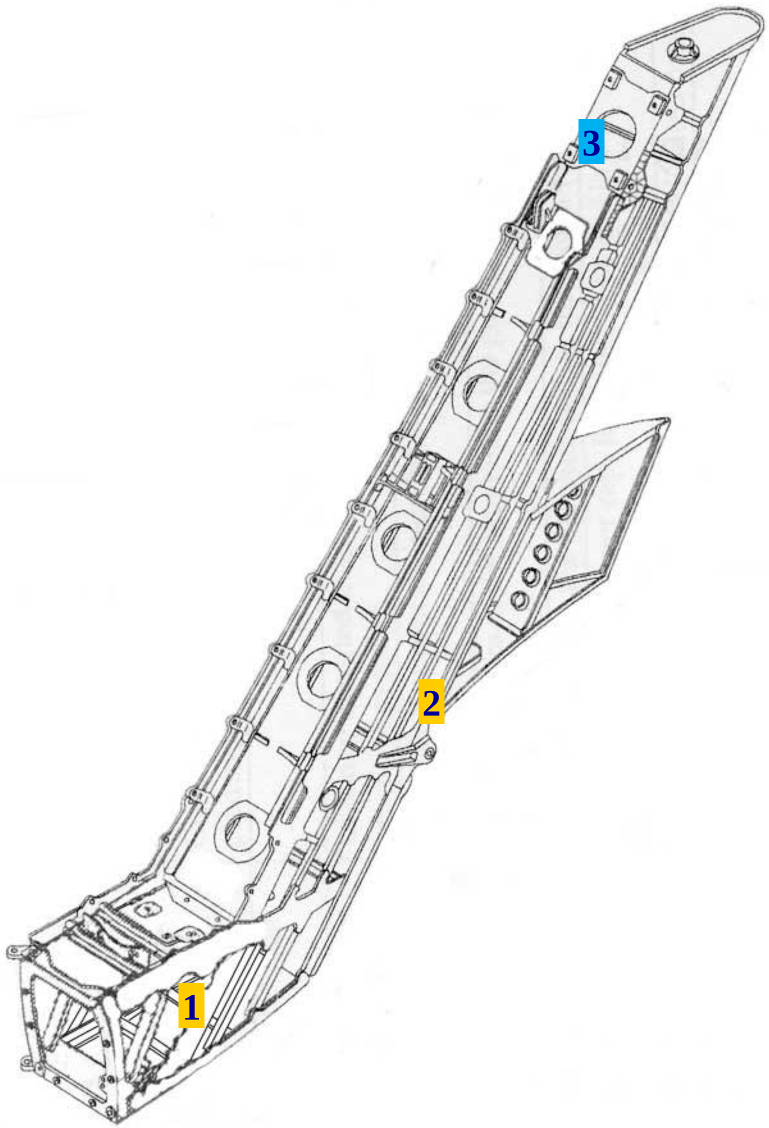


3. T/R Gear Box Fitting

S-70A-9 AIRFRAME HOT SPOTS

1. Fwd Spar Splice

2. Aft Spar Splice @ Horizontal Stab

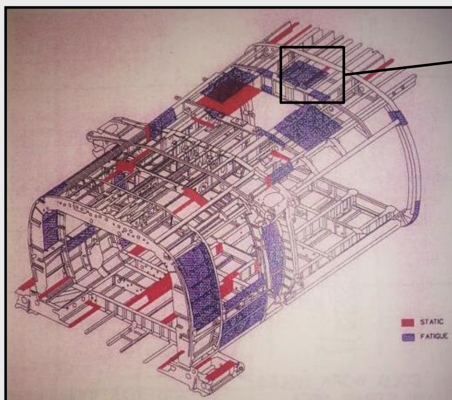


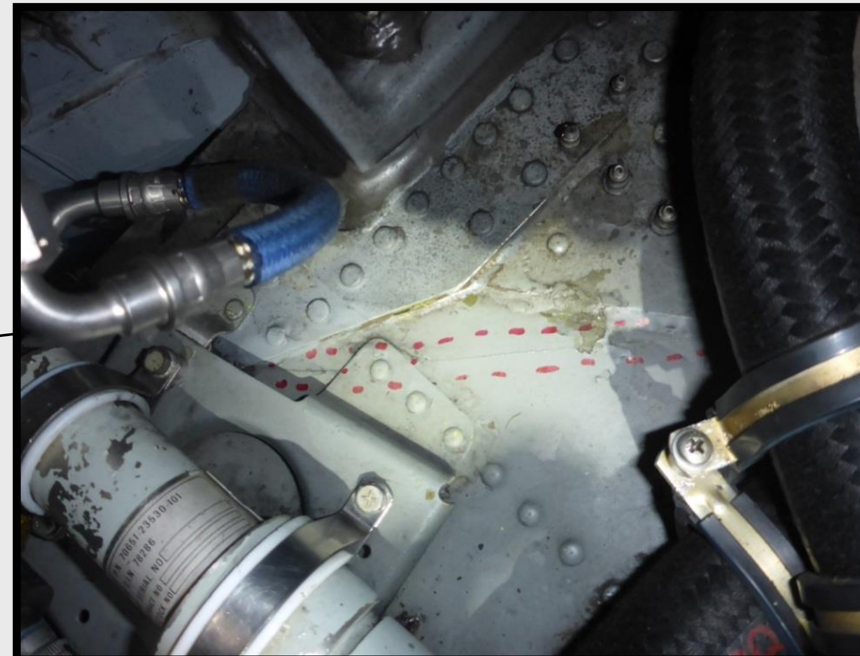
3. T/R Gear Box Fitting (QTY 4)

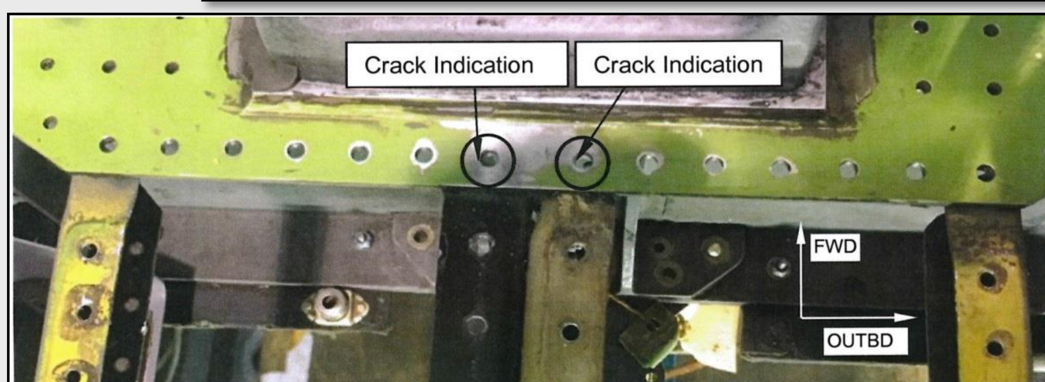
RECENT CRACKING EXAMPLES

A25-219

Nov 2016







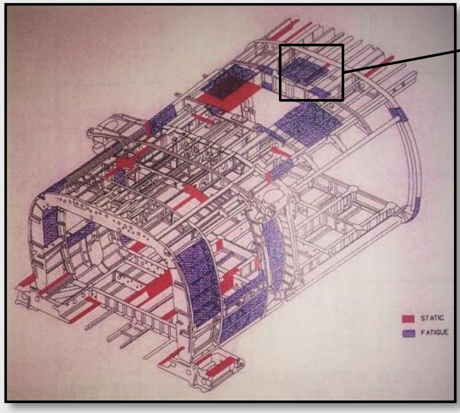
Baseline R32 servicing cost:
~$10K; 3-4 weeks

Discovery of crack:
+$51.5K; +6 weeks

RECENT CRACKING EXAMPLES

A25-112

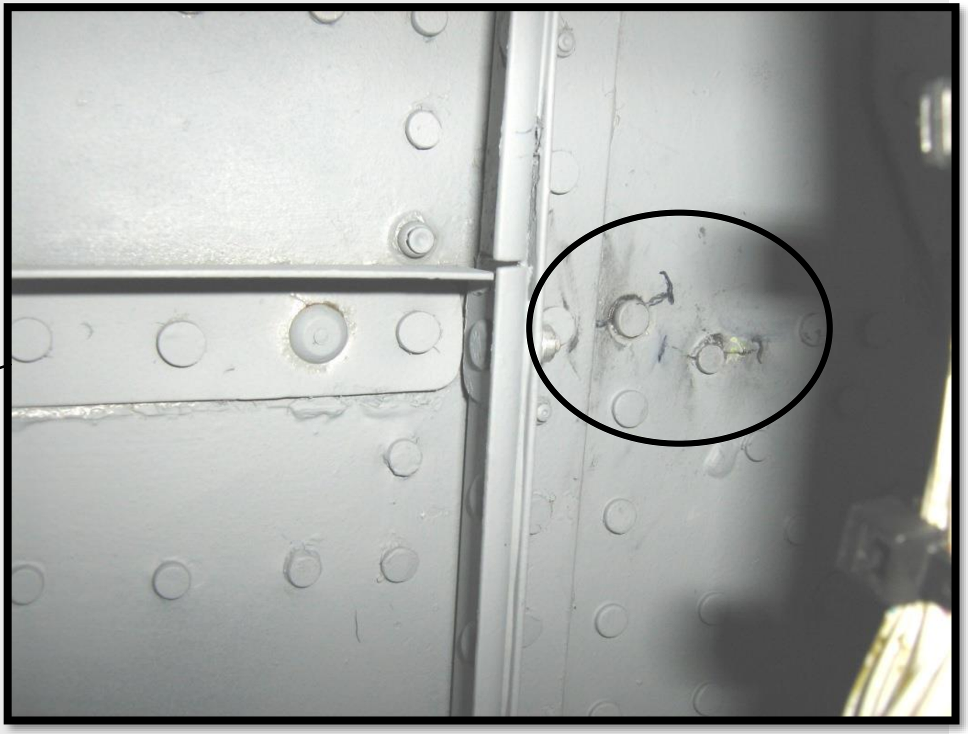
Feb 2017



RECENT CRACKING EXAMPLES

A25-215

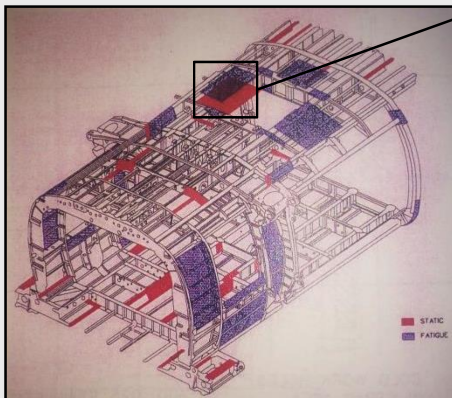
Apr 2014

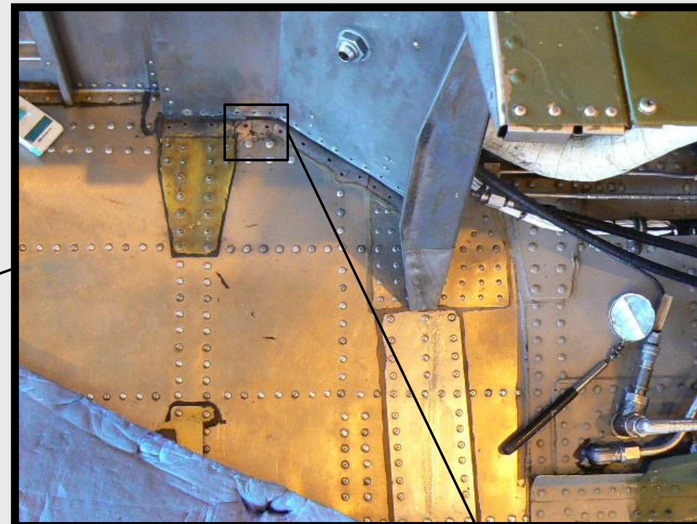


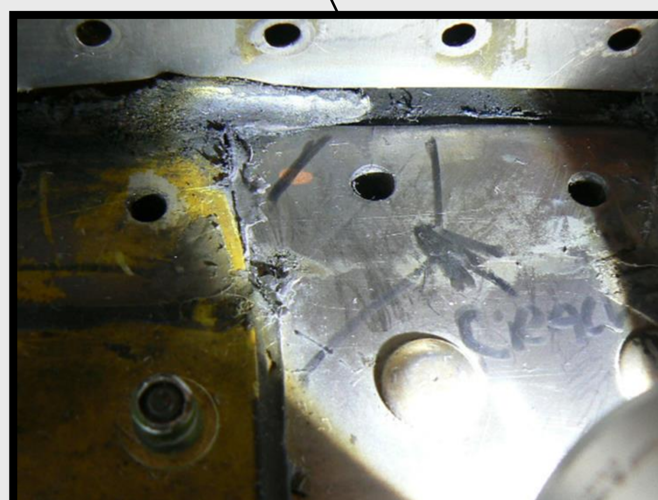
RECENT CRACKING EXAMPLES

A25-219

Jul 2014

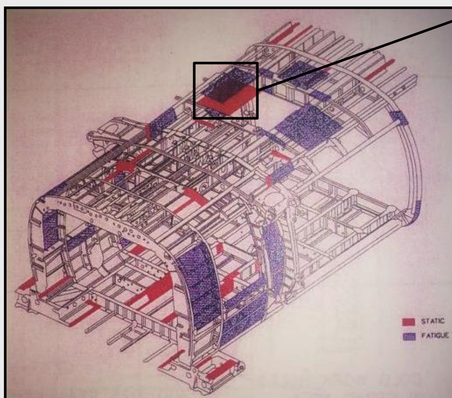


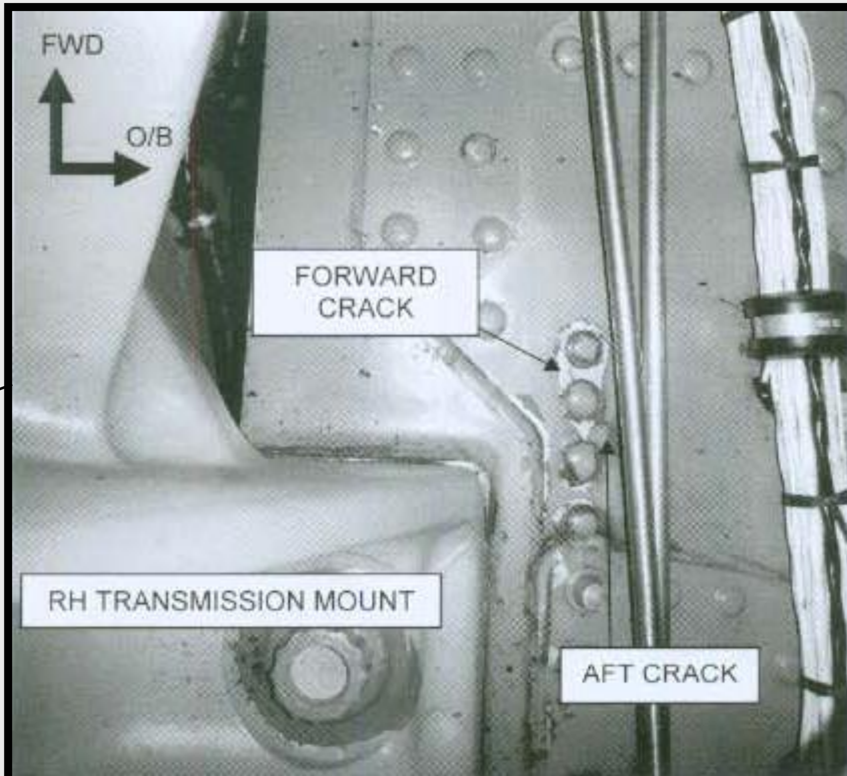




A25-106

Jul 2014

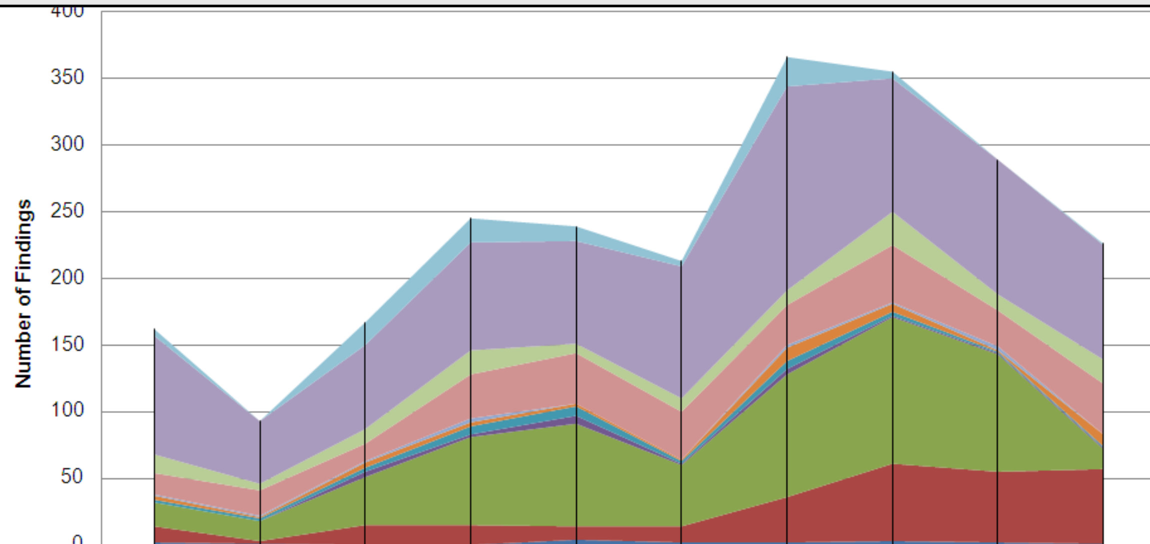




RECENT CRACKING EXAMPLES

Condition Monitoring System (CMS)

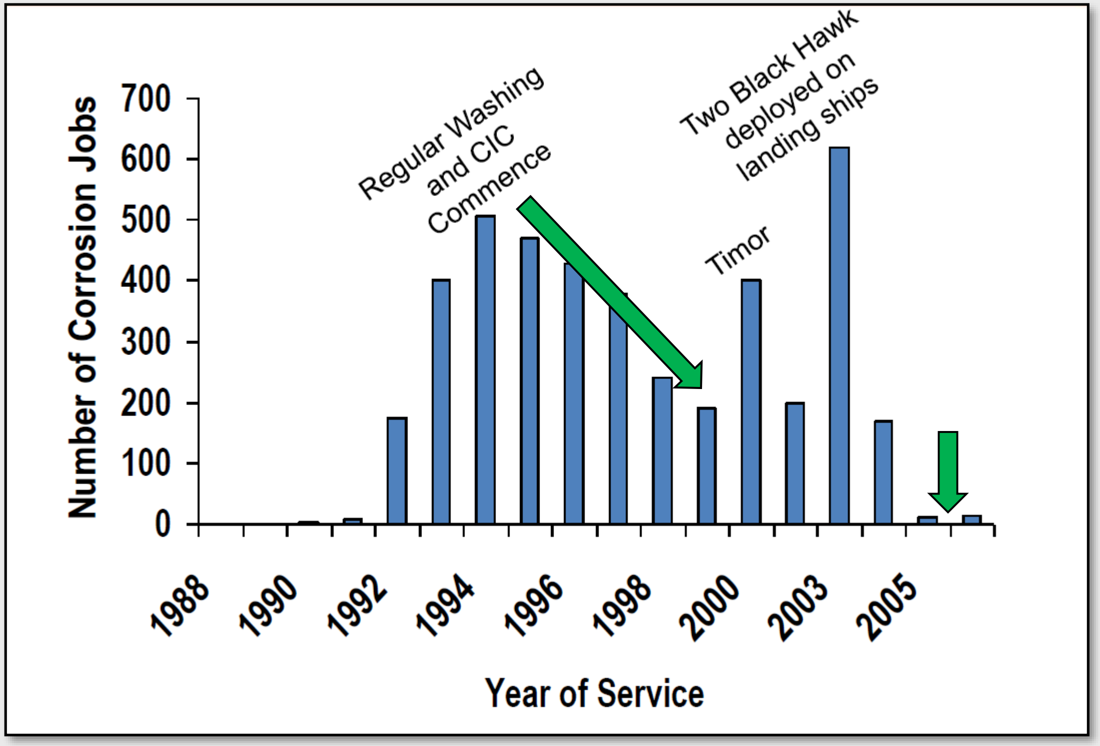
Structural Condition Assessment Report (SCAR) for Main Rotor Blade:



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Corrosion	5		17	18	11	4	22	5		1
Crack	89	47	63	81	77	99	153	100	101	86
Damage	14	5	11	18	7	10	11	25	12	18
Delaminated/Disbonded	16	19	13	33	38	36	30	43	27	38
Leak/Seal Deterioration	1	1	1	3			2	1	3	
Loose/Missing	3	1	4	3	2	1	10	6	1	9
Mechanical Damage I	2	2	3	6	7	2	6	3	1	1
Mechanical Damage II			4	2	6	1	4	1	1	1
Protective Finish/Paint Deteriorated	18	15	36	66	77	46	92	110	88	15
Worn/Deteriorated	12	2	15	15	10	12	34	58	53	56
Other	2	1			4	2	2	3	2	1

ENVIRONMENTAL DEGRADAION MNGT

- Through early 90s there was up to 50% S-70A-9 fleet unavailability due to corrosion issues
- Corrosion prevention program developed in 1994:

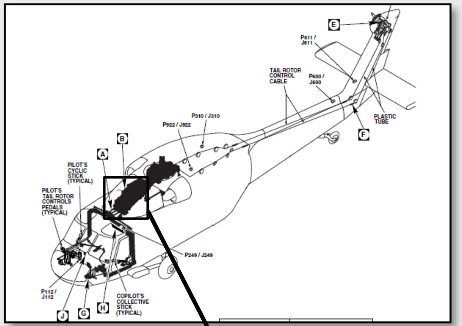


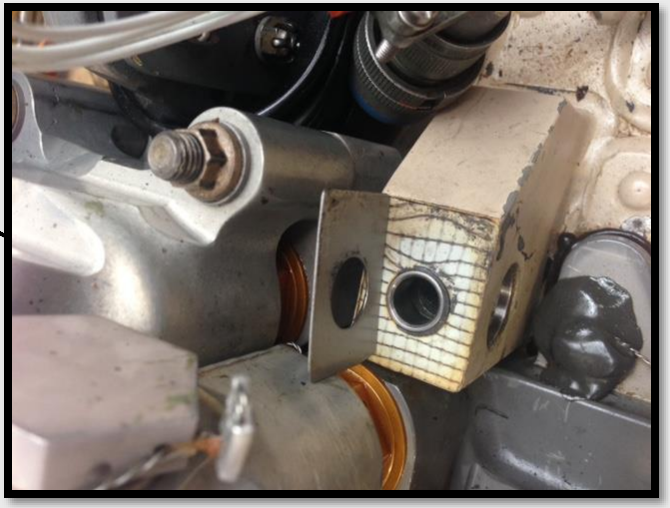
SO WHAT FOR AASPO?

- Structural degradation (‘nuisance cracking’) of airframe will be a prevalent sustainment issue for S-70A-9 through to PWD
- Increased reliance on structural engineering support
  - DASA-HSI
  - QinetiQ
  - DST-G
  - Sikorsky Helitech
- Operational demand for Black Hawk = pressure to minimise down time
  - Appetite for quick turnaround localised repairs
  - Constrained scope for fleet-wide remediation programs
  - OEM solutions may not be longer be practical
- Is there a need for introduction of targeted and rigorous inspection regimes?
  - Will need to be carefully designed in consideration of aircraft operational demand
- Are we appropriately reporting, tracking and analysing airframe cracks?

CASE EXAMPLE

Primary Servo Wear Strap Disbond





SUMMARY

- Disregard for fatigue as an airframe design criterion has subsequently challenged the service life of the aircraft
- Significant effort and resources have been (and continue to be) invested in retrospectively addressing airframe fatigue
- Development of a unique S-70A-9 usage spectrum has highlighted the sensitivity of CRTs to deviations from the DUS
- Development and ongoing verification of S-70A-9 usage spectrum is primarily based on form-based reporting
- Early investment in an Environmental Degradation Management Program has reaped significant operational and financial returns.

CONCLUSION

Lessons from the Black Hawk story:

1. Disregard for rotary wing airframe fatigue during design will come back to bite
2. Validation of the operational usage spectrum against DUS is essential
3. An instrumented usage monitoring system is a worthy investment
4. A tailored Environmental Degradation Management Program is a critical investment
5. An airframe structural management framework should match the critical dynamic component management framework