Cessna Centurion Wing Structural Assessment

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TEXTRON AVIATION

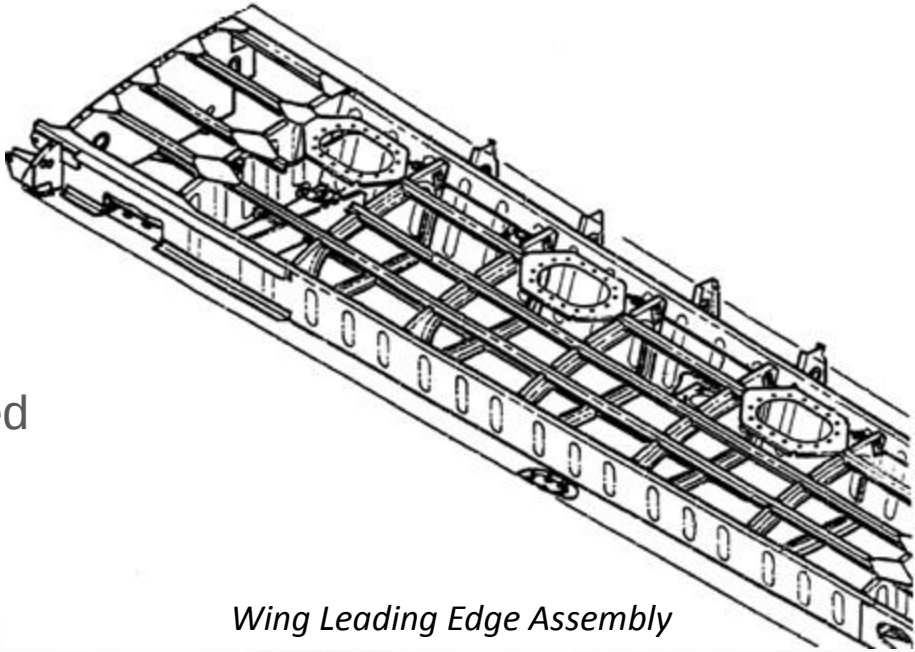
Cessna

Agenda

- Background
- Wing Spar Cap Cracking
- Initial Response
- Fleet Data Analysis
- Structural Analysis
- Residual Strength Testing
- Inspection Plan
- Conclusion

Background

- Model 210 wing (210G-210R) is an all metal wing
  - Full Cantilever
  - **Single Main Spar**
    - 210G-210N spar caps are 2014-T6511 aluminum
    - 210R spar caps are 7075-T73511 aluminum
  - Two “Fuel Spars”
    - Front fuel spar serves as auxiliary spar and the forward attachment to wing
    - Spars are .032 2024-T3 sheet
  - Formed ribs and stringers
- 7,322 210G-210R aircraft manufactured
- Used for a variety of missions
- Certified CAR 3



Wing Leading Edge Assembly

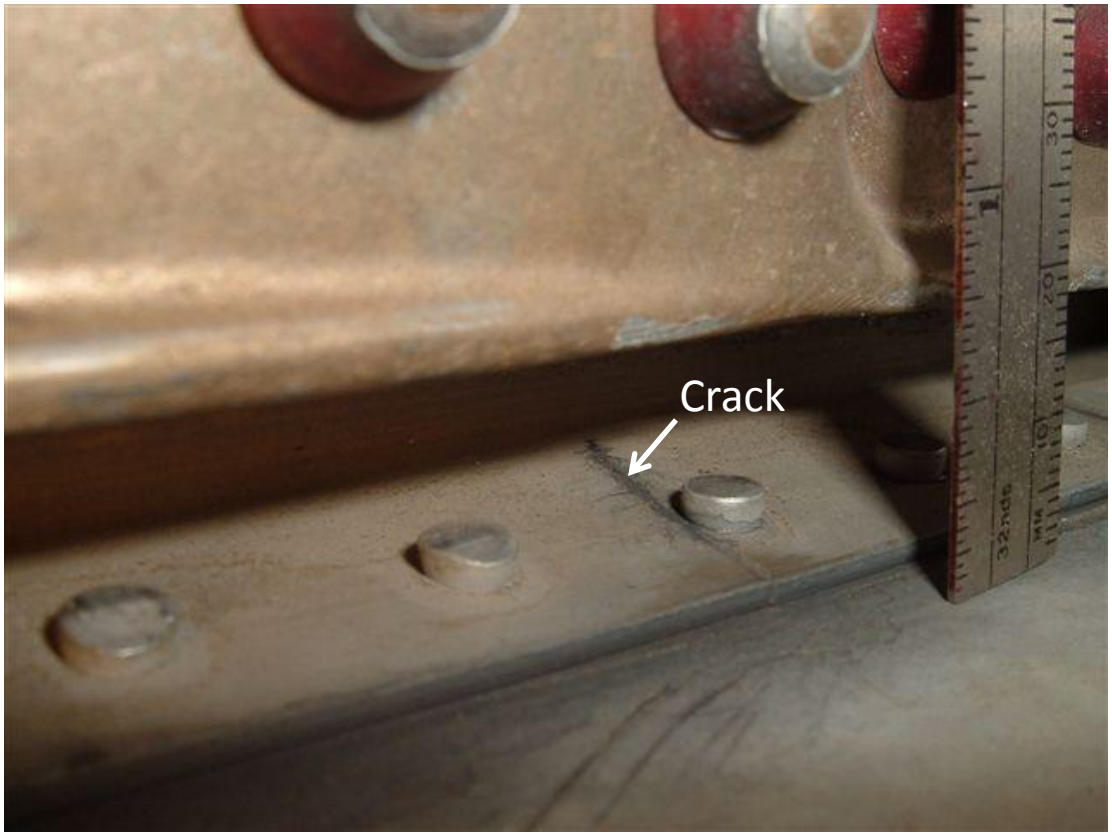
Wing Spar Cap Cracking

- April 2012 - received five reports of wing spar cracking from Australia
- Aircraft information
  - Operations
    - Three airplanes used for geophysical survey
    - Two flown in typical operations
  - Location
    - Two airplanes registered in Queensland
    - One airplane each registered in New South Wales, Northern Territory and Western Australia
  - Modifications
    - One airplane may have had wing tip tanks

Wing Spar Cap Cracking

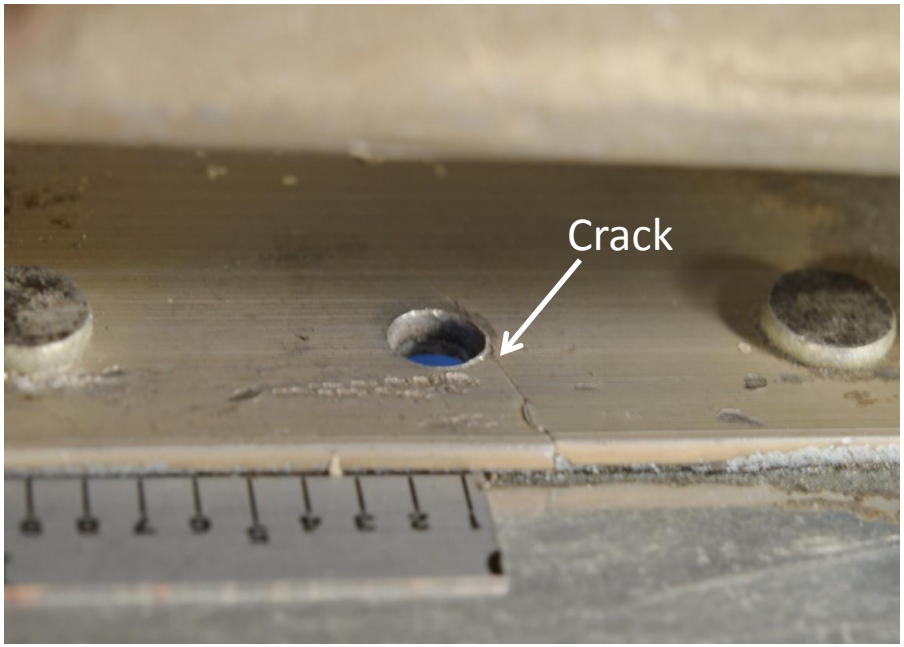
Number	Date Found	Model	Year Built	Certification Agency	Flight Hours	Known Operations	Crack Details
1	Oct-2007	210L	1976	Transport Canada	10,608	Fire fighting reconnaissance missions ~10 years	Cap 50% Severed
2	2007	210L	1973	Australia CASA	12,000	Geophysical Survey	Ligament Cracked
3	Nov-2010	210M	1978	Australia CASA	9,000	Charter/Freight	Ligament Cracked
4	Apr-2012	210R	1985	Australia CASA	15,000	Geophysical Survey	Cap 90% Severed
5	Apr-2012	210M	1977	Australia CASA	13,963	Geophysical Survey	Ligament Cracked
6	Apr-2012	210L	1975	Australia CASA	5,750	Normal Operations	Ligament Cracked
Airworthiness Directive - May 2012							
7	Jun-2012	210L	1976	Namibia CAA	7,057	Charter	Ligament Cracked
8	Oct-2012	210N	1980	Australia CASA	17,280	Charter	Ligament Cracked

Wing Spar Cap Cracking – 1976 210L

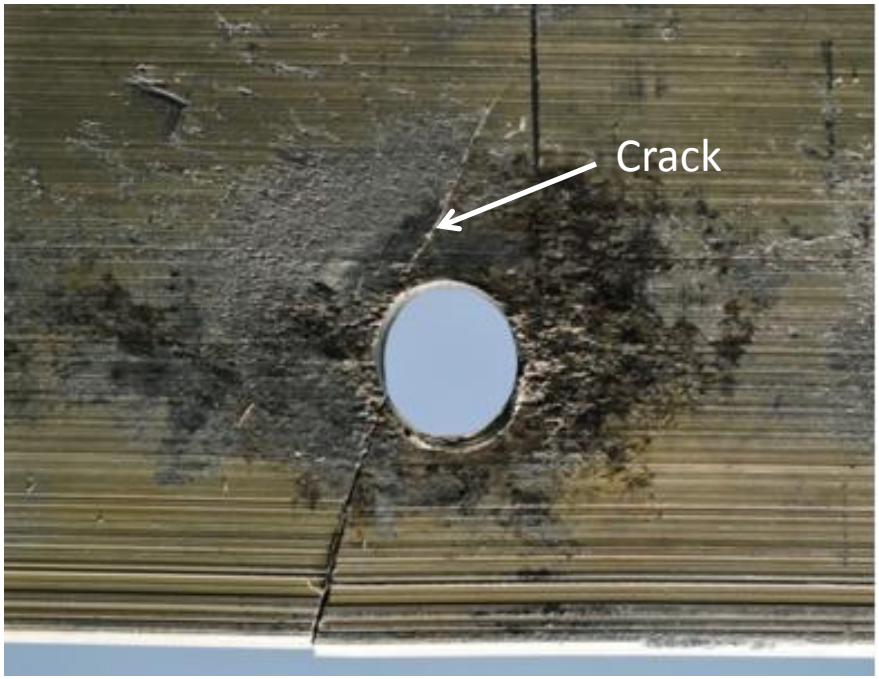


210L with 10,608 hours

Wing Spar Cap Cracking – 1975 210L



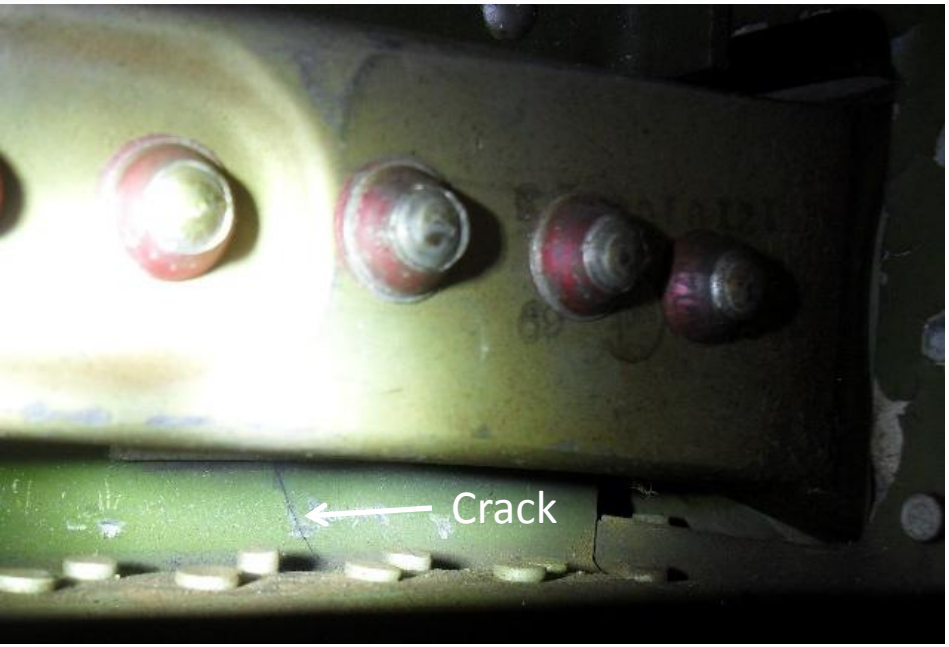
View of Spar Cap Upper Surface

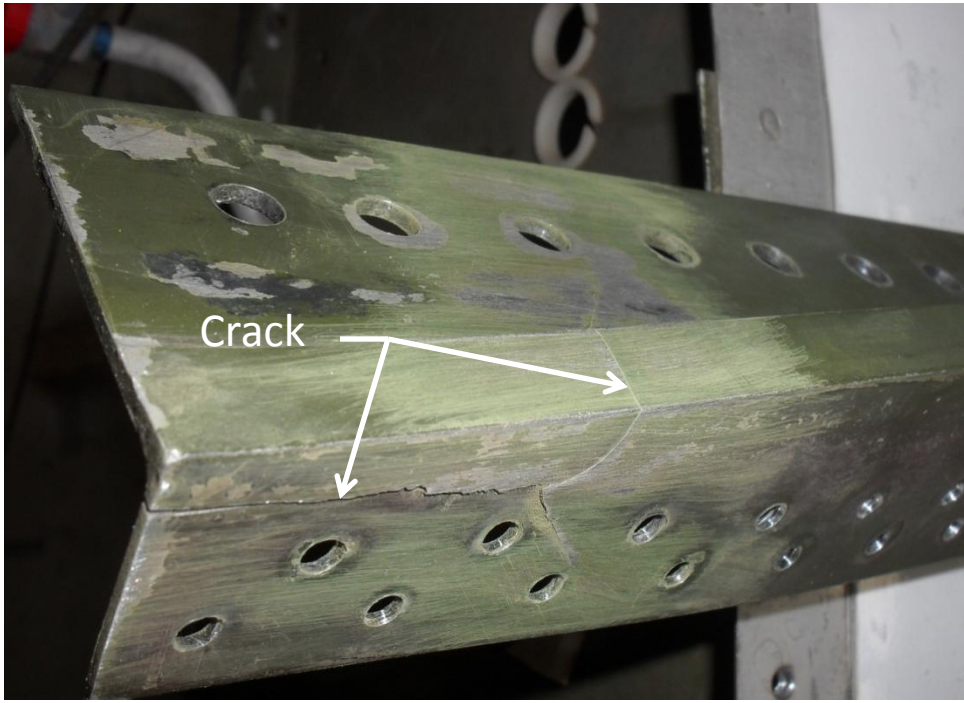


View of Spar Cap Lower Surface

210L with 5,750 hours

Wing Spar Cap Cracking – 1985 210R





210R with 15,000 hours

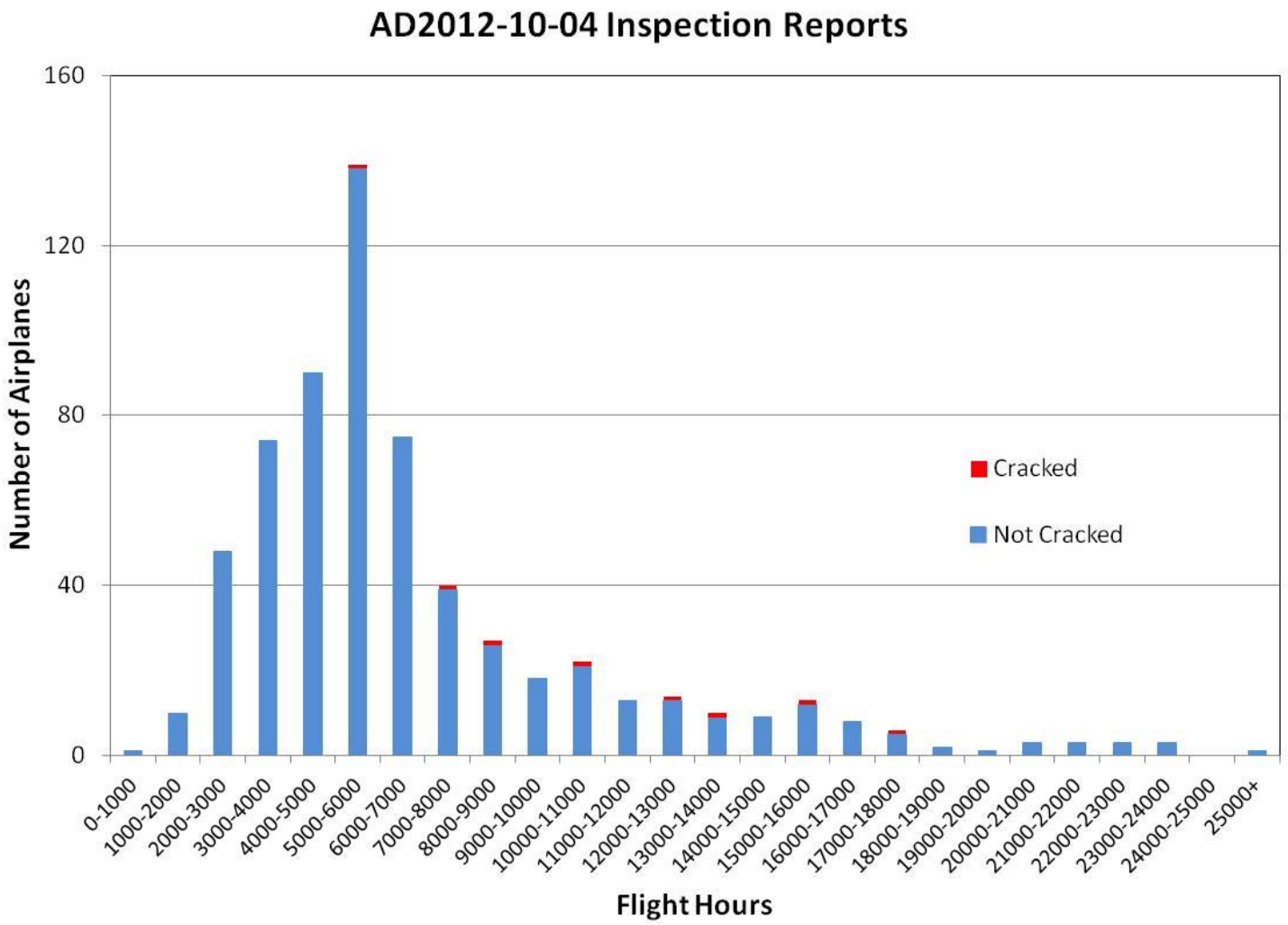
Initial Response

- Cessna Service Letter SEL-57-01
  - Visual inspection of spar cap at fitting
  - Inspection times
    - Airplanes over 10000 hours
      - Perform inspection within 5 hours, repeat every 500 hours
    - Airplanes over 5000 hours
      - Perform inspection within 25 hours, repeat every 500 hours
  - Reporting form included in service letter
  - Repair is replace cap, spar assembly or wing
- FAA issued airworthiness directive to mandate inspection and report findings (one-time only)

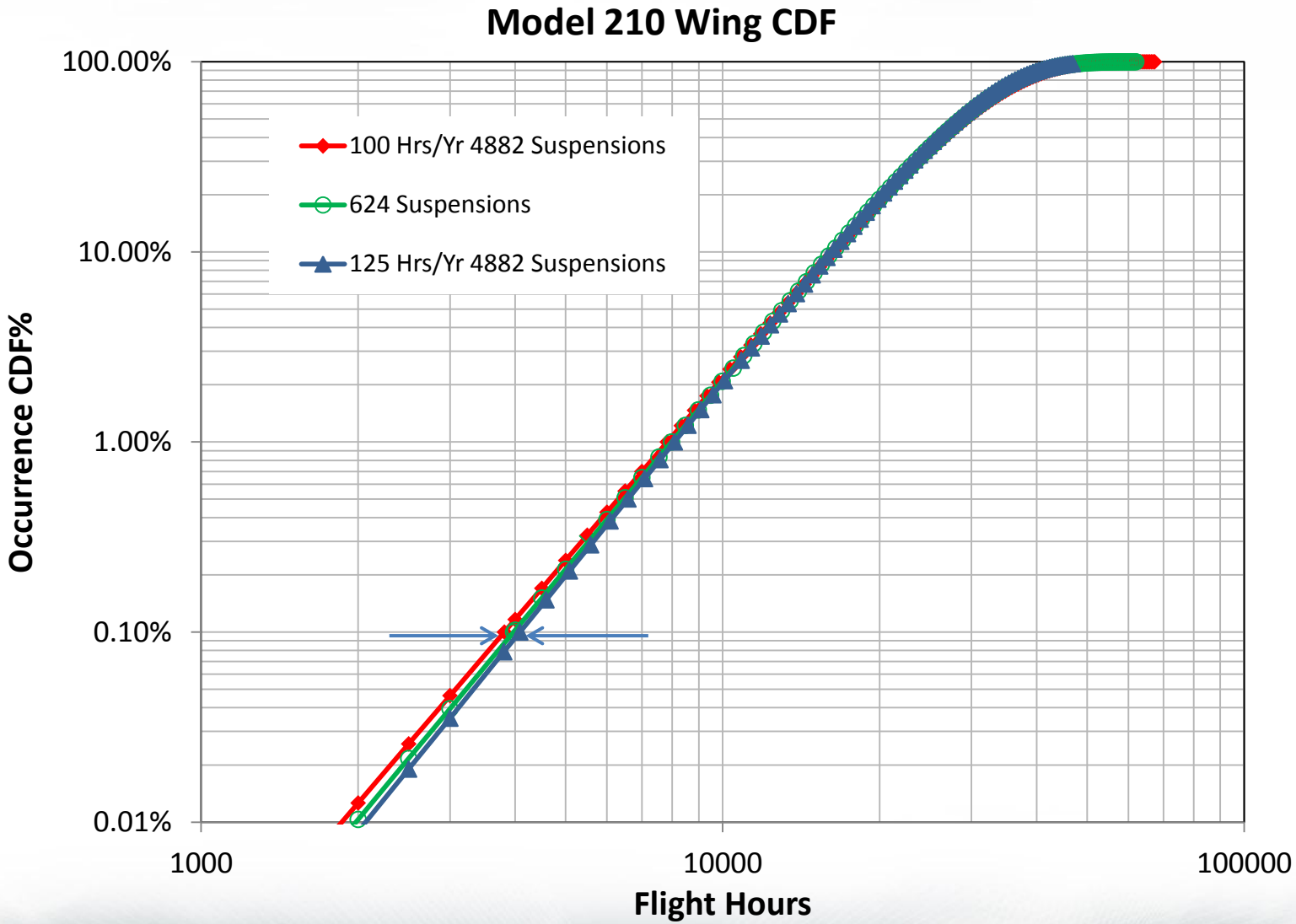
Fleet Data Analysis

- 632 airplanes were inspected per AD2012-10-04
  - Two additional airplanes were found to have ligament cracks
- Weibull analysis completed using inspection reports
  - Assumed 4,882 suspensions based on 7,322 airplanes manufactured minus 2,440 included in NTSB database
  - Analysis conducted with and without suspensions
  - Analyzed non-reporting fleet assuming 100 and 125 annual flight hours

Fleet Data Analysis



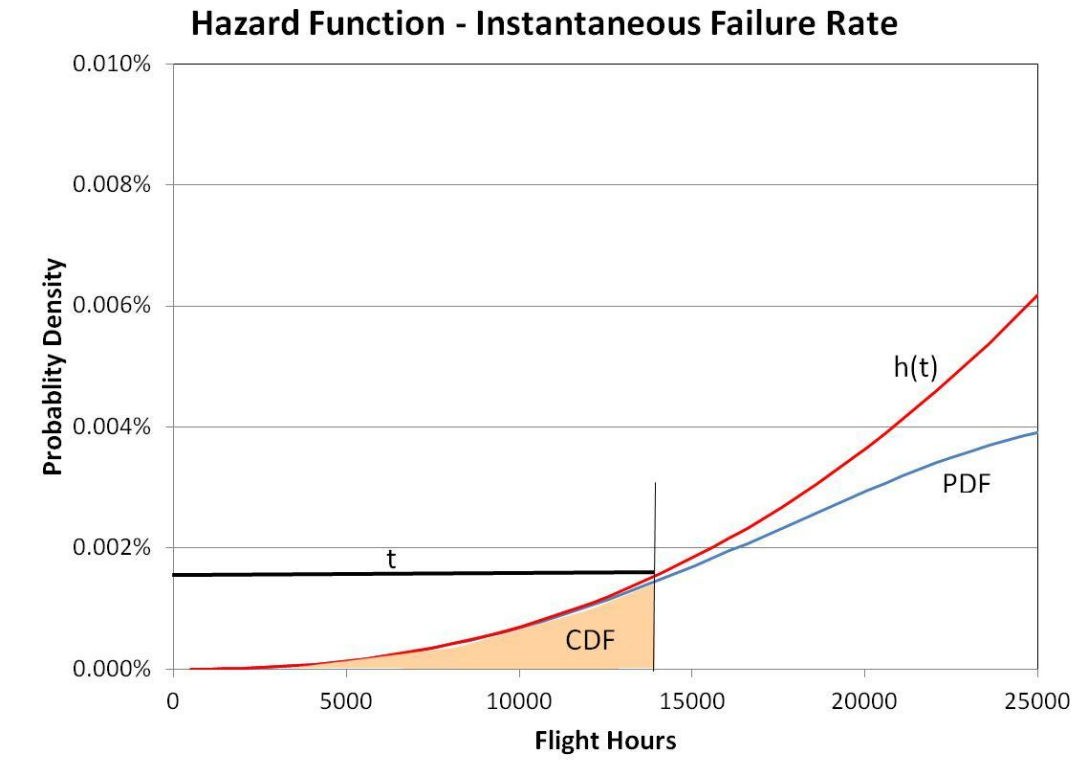
Fleet Data Analysis



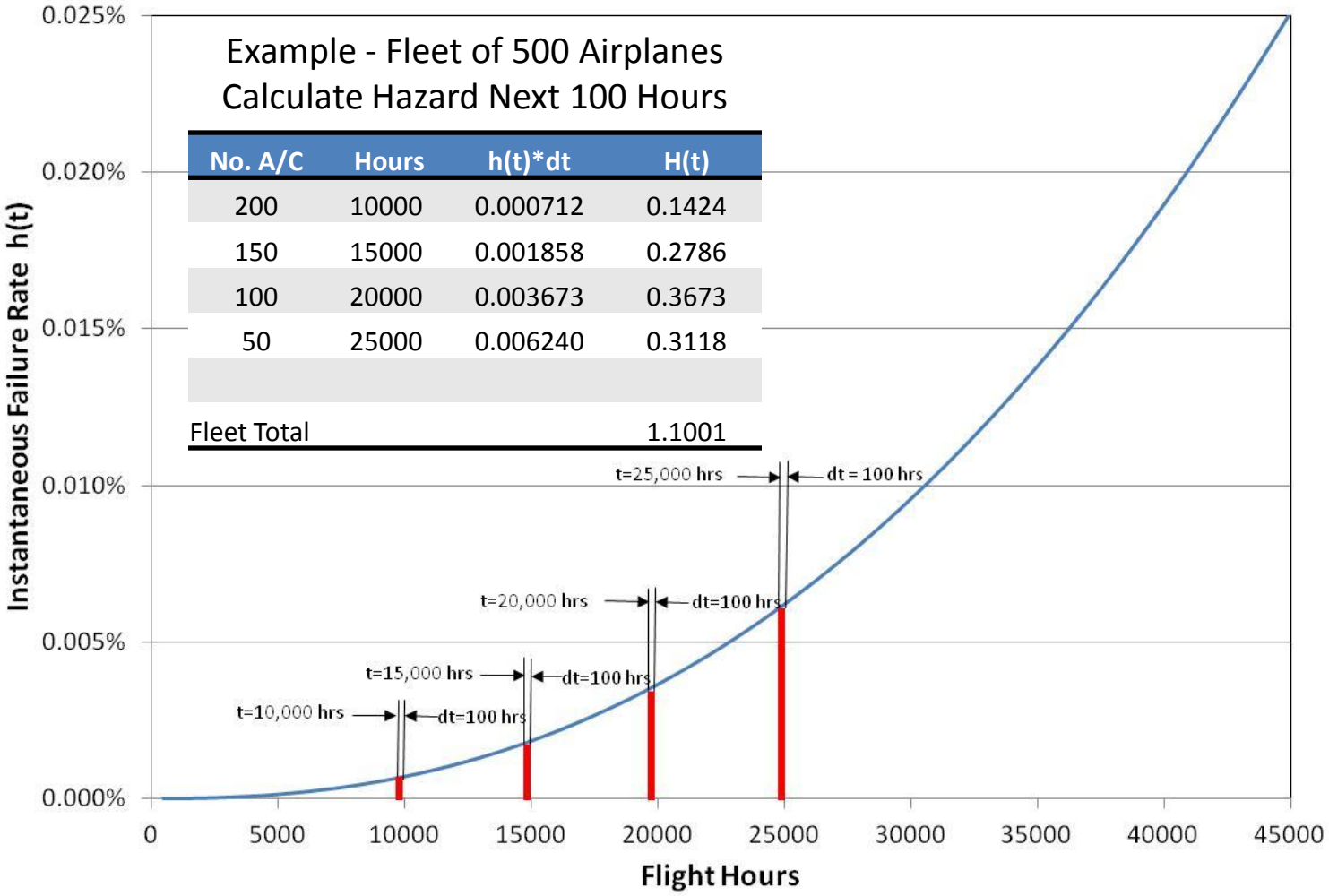
Fleet Data Analysis

- Hazard function h(t) used to determine instantaneous failure rate
  - Interpretation: Consider a single aircraft that found no failed spar at time t. The chances of having a cracked spar in a small interval [t,t+dt] are then given by H(t) ≅ h(t) dt

$$Hazard\ Function\ h(t) = \frac{PDF(t)}{1 - CDF(t)}$$

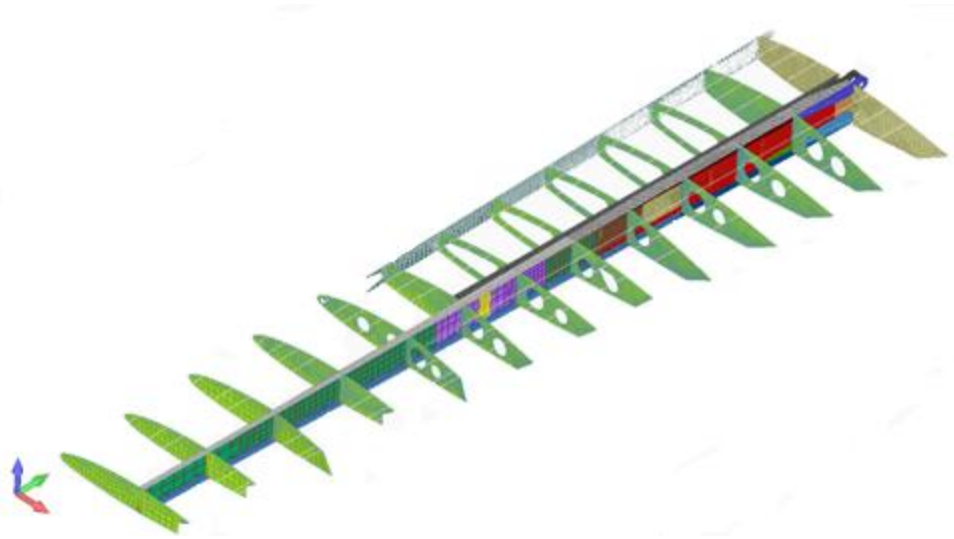


Fleet Data Analysis



Structural Analysis

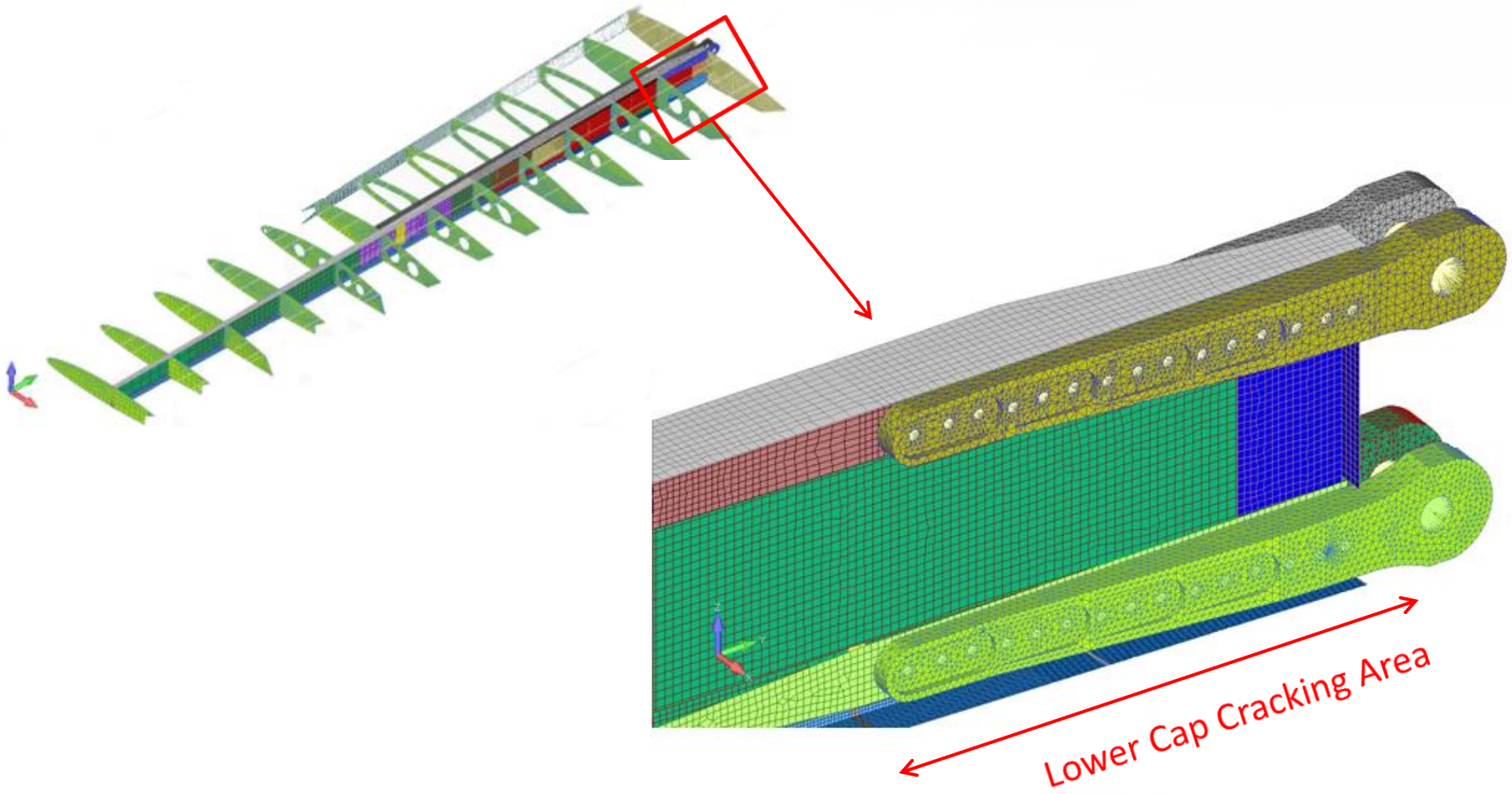
- Goal of analysis is to determine if inspection program is feasible
  - Determine crack propagation rate
  - Determine residual strength capability
- Conducted flight strain survey on a Model 210M
- Developed detailed finite element model (FEM) of wing structure



Wing FEM - Skins Removed for Clarity

Flight Strain Test Airplane

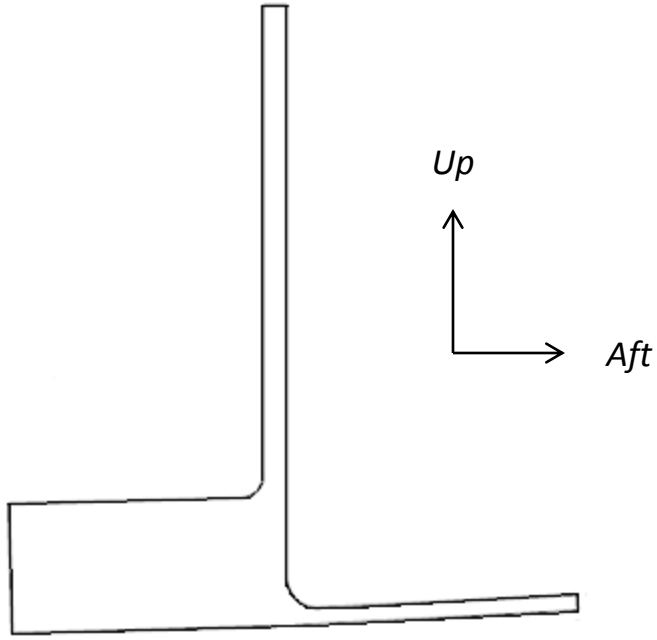
Structural Analysis



Model 210 Wing Spar Finite Element Model

Structural Analysis

- Analysis Opportunities
  - Develop spectrum representative of the fleet
  - Ability of spar cap to arrest crack starting in ligament
  - Two spar materials:
    - 2014-T6511 (Models 210G-210N)
    - 7075-T73511 (210R)



Model 210 Spar Cap Cross-Section

Structural Analysis

- Spectrum development
  - FAA Advisory Circular AC23-13A exceedance curves used to develop flight spectrum
  - Assumed two flight profiles based on Cessna Service Letter SEL-57-01 reports
    - Typical profile
    - Severe profile
- Fatigue and crack growth evaluations
  - Typical spectrum calculated fatigue life correlates well with fleet data
  - Majority of crack growth life remains in cap after ligament breaks
- Residual strength analysis
  - ABAQUS model developed to evaluate residual strength capability of a cracked spar
    - ABAQUS model verified by residual strength testing

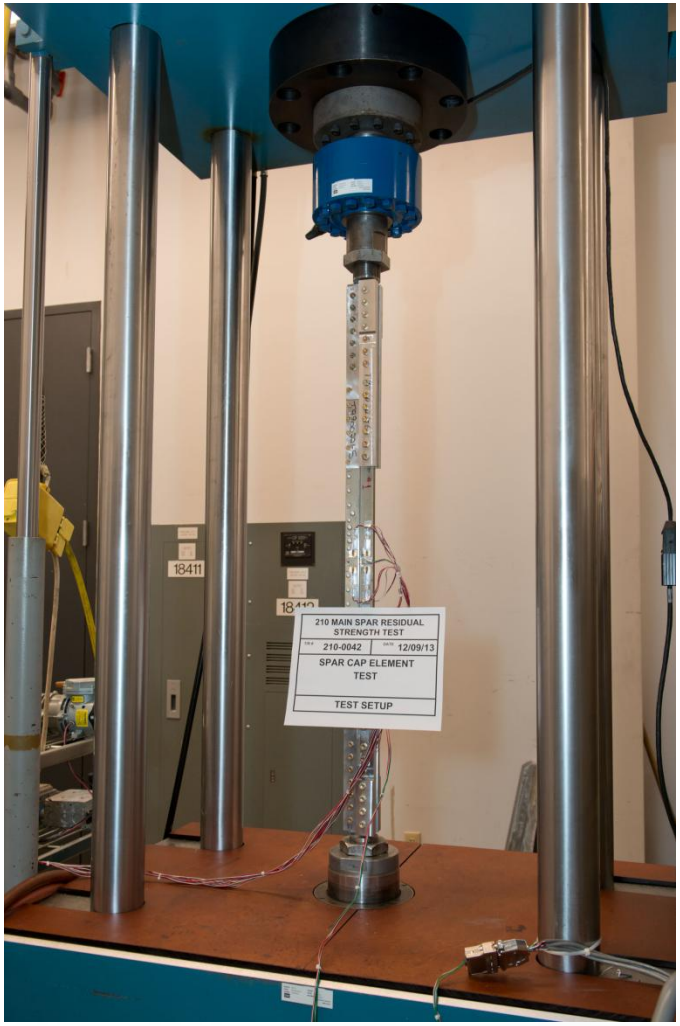
Residual Strength Testing

- Testing conducted to determine if a 2014-T6511 spar cap has sufficient residual strength to hold limit load with a crack present
  - Model 210 wing spar assembly was obtained from a salvage yard
    - Test #1
      - Spar assembly (upper and lower caps plus web) was cyclic tested
    - Test #2
      - Section of spar cap with natural crack was placed into MTS machine and loaded to ultimate load

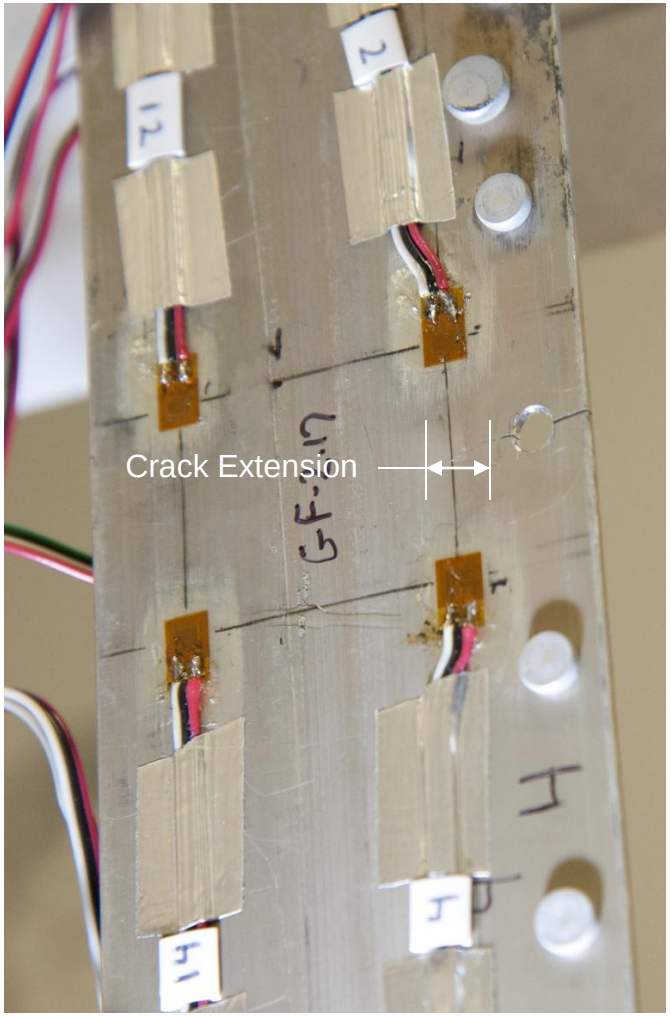
Residual Strength Testing – Test #1

Model 210 Wing Spar Assembly

Residual Strength Testing – Test #2



Test Setup



Post-Test Crack Extension

Inspection Plan

- Revised Cessna service letter SEL-57-01 to include new inspections
- Added inspection to
  - Model 210 Service Manual (Supplemental Inspection 57-11-03)
  - Airworthiness Limitations Section
- Inspection plan is for unmodified airplanes
- Model 177 Cardinal has similar inspection plan

Inspection Plan

Visual Inspection

	Typical Usage		Severe Usage	
Material	Initial (hrs)	Repeat (hrs)	Initial (hrs)	Repeat (hrs)
2014-T6511	5,000	100	3,000	100
7075-T73511	4,000	100	2,500	100

Eddy Current Inspection[1]

	Typical Usage		Severe Usage	
Material	Initial (hrs)	Repeat (hrs)	Initial (hrs)	Repeat (hrs)
2014-T6511	8,000	2,000	3,500	500
7075-T73511	5,500	2,000	2,800	500

[1] *Eddy current inspect around the fasteners and along the radius from WS 26 to WS 40*

Conclusion

- Model 210 fleet can be kept airworthy up to the 30,000 hour retirement life with added wing inspection
- Safety is a partnership between owners (maintainers), manufacturers and the FAA/CASA
- Report anomalies to the manufacturer customer service
  - Cracking of major structural elements needs to be reported immediately