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Amélioration de l'état de préparation opérationnelle grâce à l'excellence du soutien

Canadian Forces GBEHC PoD Presentation to the Model Assisted PoD Working Group

Orlando, FL 22 Sept 2005

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Outline

- Project Objective
- Project Methodology
- Timelines
- Cost
- Other PoD work
- Conclusion

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Projective Objectives

- To validate the current minimal detectable crack size (a_{NDT}) in fastener holes representative of a box wing structure using Rotating Bolt Hole Eddy Current (RBHEC)*
- To verify a PoD model so that the PoD of defects in similar structures can be interpolated

*Also known as ABHEC

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Project Objective (Cont’d)

- As much as possible the intent of this project is to have a generic PoD study
- Conventional PoD studies are limited to the exact structure inspected
- This project will use a combination of actual test data and models
- By use of the models the real PoD results can be applied to similar structure (generic)
- This approach will be more cost effective than conducting many specific PoD studies

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Methodology

- The PoD study will consist of three different sources of defects (cracks):
  - Real cracks from P3 spar caps and wing planks
  - Manufactured cracks (in an assembly representative of box wing structure)
  - EDM notches
  - (Possible manufactured cracks from another manufacturing methodology)
- These structures will be sent to various Canadian Forces (CF) NDT facilities and possibly CF contractors for testing

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Methodology – Real Cracks

- The focus of this project is to use real cracks from a box wing structure
- Real cracks to come from P3 structures: SLAP* leftovers, and planks/webs/spar caps removed from USN P3s. The quantity and size of these defects is unknown and will not be known until destructive testing is performed on each fastener hole (Fractography)

* Service Life Assessment Program – a joint CAF/USN/RNAF project where a P3 outer wing was fatigued to failure and torn down for inspection. Both NDT and DT were performed to understand the wing failure mechanism

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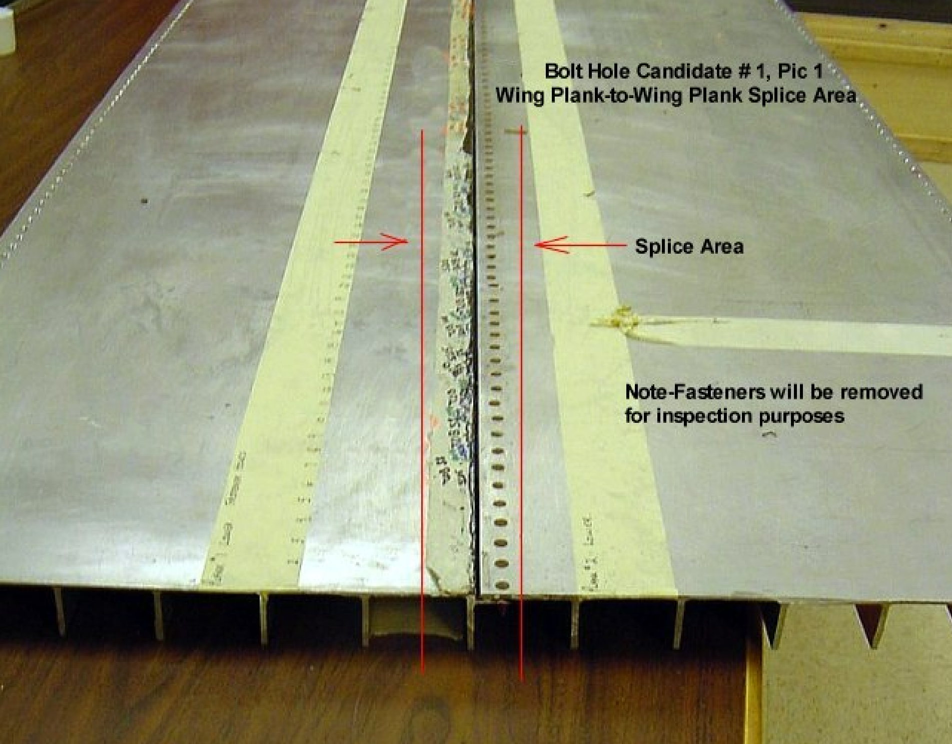
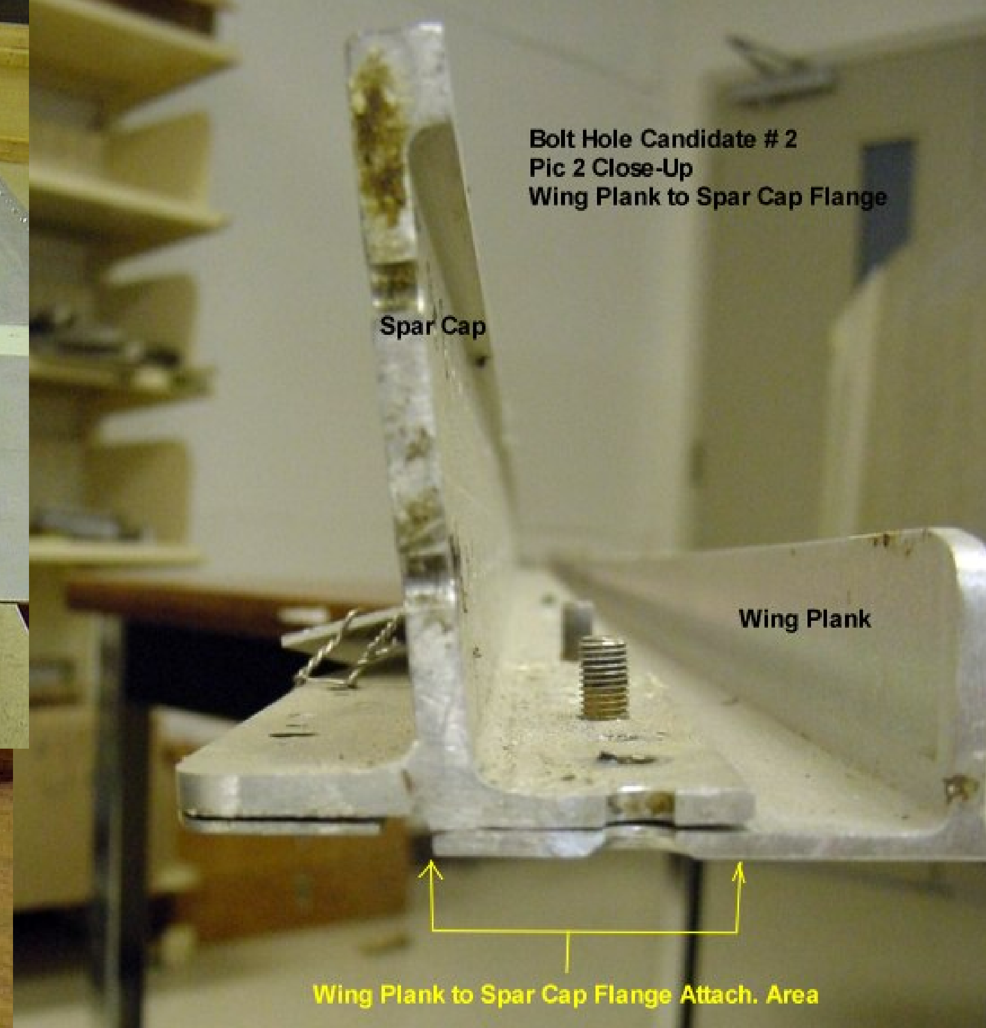
Methodology – Real Cracks

- Although the size and quantity will be unknown, an estimation of the amount and size will be given by an expert NDT technician using RBHEC, BHEC, LPI, and video microscope
- This number will influence the amount of manufactured cracks required





Real cracks from real structure

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Methodology – Manufactured Cracks

- As a back up and to ensure statistical soundness of the study, cracks will be manufactured (grown), measured, and be included in the study
- This component of the project is very important as a minimal amount of cracks of a specific range in sizes is needed for the PoD Study to be valid
- The manufactured cracks will represent a skin splice, spar-to-web, and skin-to-spar joints

Methodology – Manufactured Cracks

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- The number of manufactured crack specimens is dependent on the number of real cracks that can be found in existing structure (more real cracks = less manufactured cracks)
- Obviously cracks that are smaller than the threshold of detection will not be found in real structure and therefore a minimum number of manufactured cracks will still be required

Methodology – Manufactured Cracks

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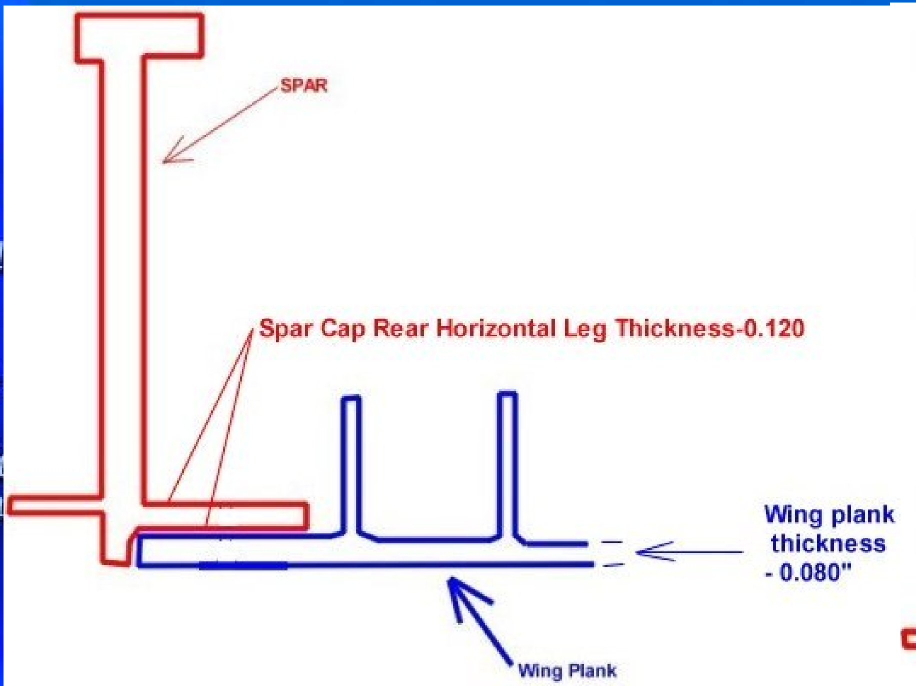
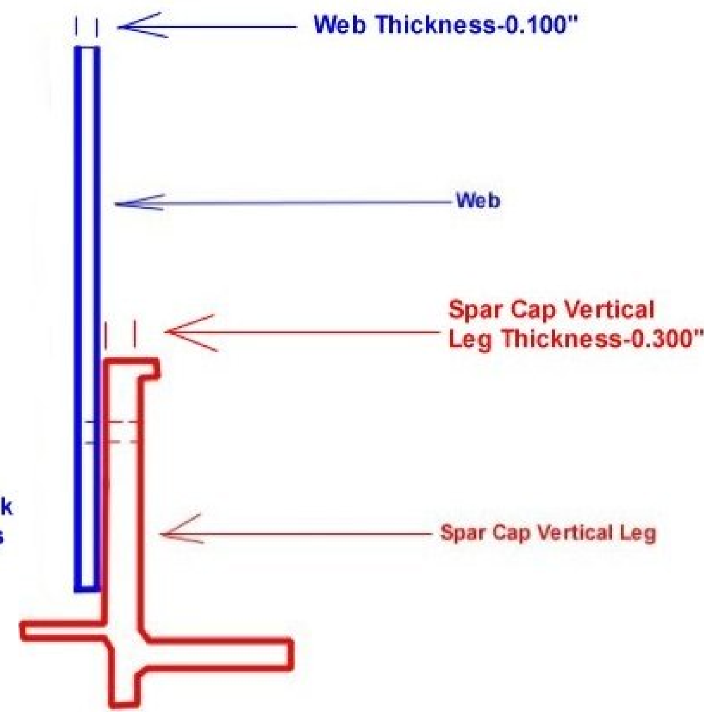
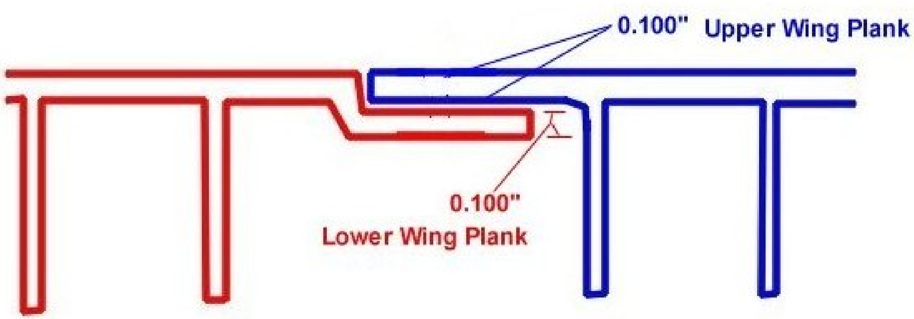


Wing Plank Splice Thicknesses





Cracks will be grown in specimens representative of a box wing structure

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Variables and Levels

Variable	Levels
Location, L	L1 1st Layer
	L2 2nd Layer
Skin Thickness, T	T1 0.080"
	T2 0.090"
	T3 0.125"
	T4 0.312"
Hole Diameter, D	D1 3/16"
	D2 1/4"
Crack Type, C	C1 EDM notch
	C2 Lab Crack
	C3 Fatigue Crack
Crack Origin, O	O1 Mid-bore
	O2 Corner
Inpsection Technique, I	I1 DND
	I2
	I3 Interpret Saved Signals
Inpsector N	Inspector 1
	Inspector 2
	…

Manufactured Cracks Variables and Levels

- D1, L2, T2, O1
- D1, L2, T2, O2
- D1, L2, T4, O1
- D1, L2, T4, O2

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NRC / QETE Participation

- National Research Council of Canada (NRC) to manufacture specimens with holes
- Quality Engineering Test Establishment (QETE) to perform wire EDM slotting (one side each hole)
- NRC to fatigue the specimen to obtain >30 cracks in the 0.005” to 0.050” range (other sizes outside this range are important to have as well!)
- NRC to prepare holes to final size, provide nominal additional fatiguing to the coupons (~500 additional fatigue cycles to sharpen crack and help eliminate crack smearing), document / measure the created cracks under load

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NRC / QETE Participation

- NRC to ID label and excise the holes creating 1.5” x 3” reference coupons
- QETE will undertake destructive fractographic documentation of selected cracks

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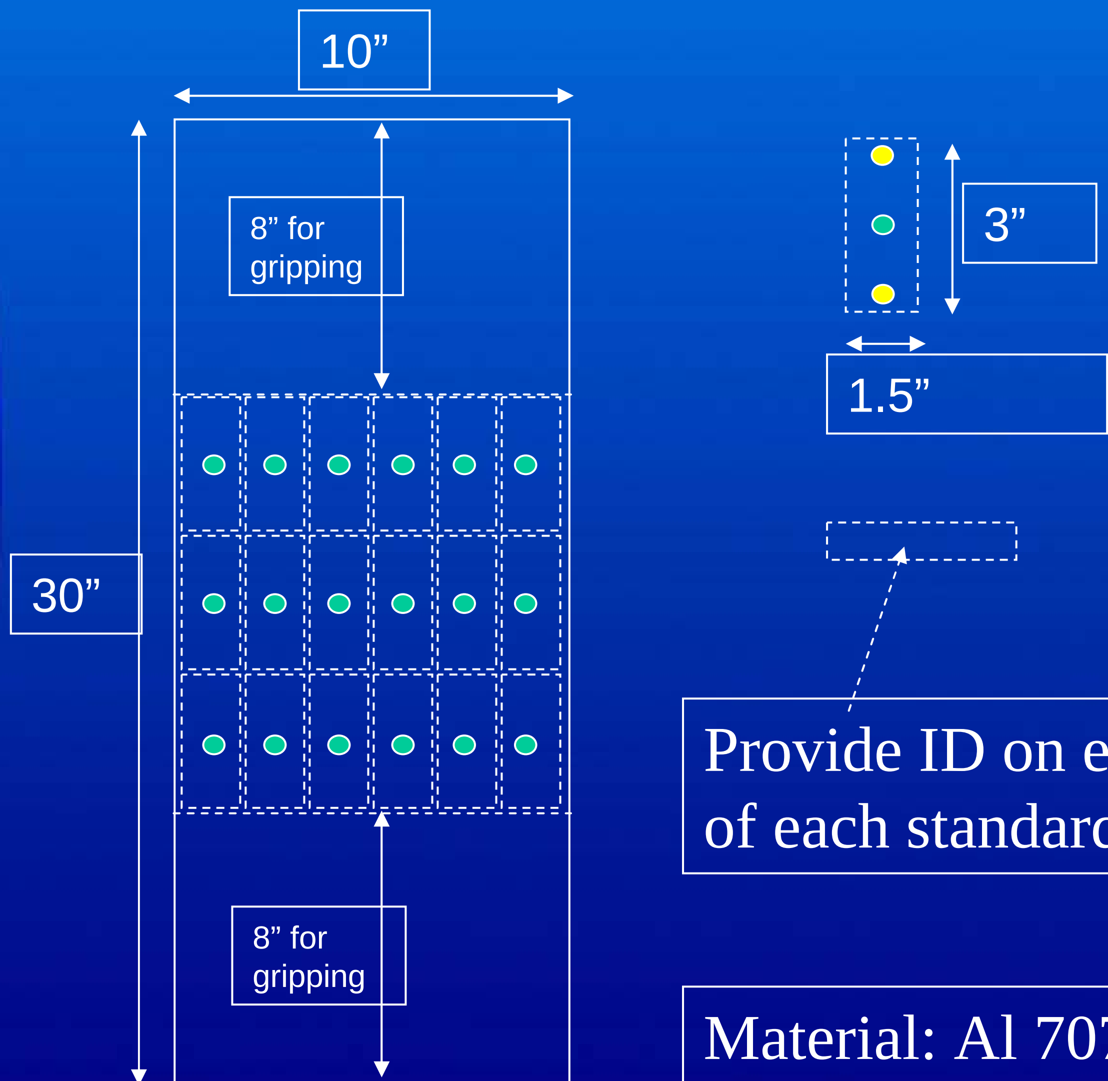
Specimen Conceptual Drawing



dimensions in inches

Provide ID on end of each standard

Material: Al 7075-T6

“Thick Specimen” With Corner Cracks - Conceptual Drawing

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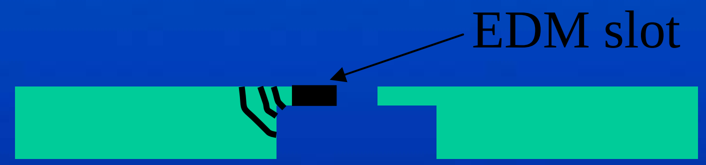
Hole X-Section Details for Corner Crack

Machine 12 undersized pilot holes and create thin lips using end mill / flat bottom drill



EDM slots using 0.004” diameter wire (@ QETE). Generate fatigue cracks of “appropriate size”.

Drill / ream holes to final size. Measure crack sizes (of all the cracks created we need at least 30 cracks in the 0.005” to 0.050” range).

Specimen size is limited to 10” by 30” to fit the QETE wire EDM machine

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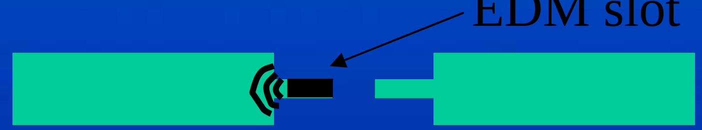
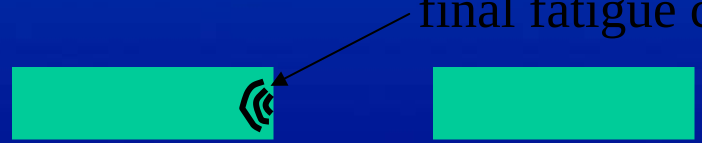
"Thick Specimen" With Mid-Bore Crack - Conceptual Drawing

Hole X-Section Details for Mid-Bore Crack

Machine 12 undersized pilot holes and create thin lips using end mill / flat bottom drill



EDM slots using 0.004" diameter wire (@ QETE). Generate fatigue cracks of "appropriate size".



Drill / ream holes to final size. Measure crack sizes (of all the cracks created we need at least 30 cracks in the 0.005" to 0.050" range).

Specimen size is limited to 10" by 30" to fit the QETE wire EDM machine

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Hole Numbers

- Assume a 50% success rate of creating the appropriate cracks in the range of 0.005” to 0.050”
  - need 4 specimens for each thickness and crack type (4 x 18 = 72 holes)
  - for 2 thicknesses x 2 crack types x 72 holes = 288 holes (ref stds), plus min 3 x 160 = 480 defect free holes
  - Therefore should have approx 768 holes for the PoD study
- NRC has had success with this methodology in the past
  - F5 Golden Triangle test coupons

Fatigue Considerations

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- Fatigue parameters
  - constant amplitude
  - R (Pmin / Pmax) = 0.1
  - max stress in the 10 to 15 ksi range
  - 10 Hz sinusoidal waveform
  - load levels should be adjusted so that cracks form between 50,000 and 150,000 fatigue cycles
  - assume 5 machine hours per coupon (5 hours x 10 Hz x 3600 cycles per hour = 180,000 cycles) + 5 hours labour

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Fatigue Considerations

- Fatigue Process Steps
  - initial setup of fixtures
  - install specimen, apply fatigue cycles and monitor cracks
  - reinstall specimen with final machined holes
    - apply 500 additional fatigue cycles to sharpen crack and help reduce crack smearing effect at hole edge
  - conduct measurement / documentation of reference cracks under load

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Methodology – EDM Notches

- As part of the study EDM notches in similar structures will also be studied
- Crack signal response and probability of detection between real cracks and EDM notches will be compared
- This information is very useful to both the NDT engineers and the structural engineers as calibration blocks for inspection are typically made with EDM notches

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Overall Project Variables and Levels

- D1, L2, T2, O1
- D1, L2, T2, O2
- D1, L2, T4, O1
- D1, L2, T4, O2
- D1, EDM Notches T2,O2
- D1, EDM Notches, T1, O2
- D1, Fatigue Cracks (various T & O)

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Methodology - SLAP

- As part of this project, results from the P3 SLAP project will be studied
- There is sufficient data from the SLAP project to conduct a small PoD study
- This data should be available in Oct 2005

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Fractography

- Cracks parameters from the P3 spar caps and wing planks will be determined at QETE using fractography
- Some of the manufactured cracks will also be ‘fractoed’ to validate lab measurements of the cracks
- EDM notches do not require fractography

ATESS Timelines

- Crack harvesting currently underway from SLAP leftovers and USN P3 planks/webs/spar caps -> many small cracks found to date
- ATESS will catalogue cracks as discussed previously and provide results to NRC to include in the DOE – Nov 2005
- EDM notches – Jan 2005
- Prepare for inspections – Feb 2006
- Conduct Inspections - Mar 2006

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NRC Phases and Timelines

- Phase 1: Specimen manufacture validation – Oct 2005
- Phase 2: Specimen manufacture – Mar 2006
- Phase 3: Inspection - Mar 2006
- Phase 4: Eddy Current Model Design and Validation – Jan 2006
- Phase 5: Selected Teardown – Mar 2006
- Phase 6: Data Analysis – Sep 2006
- Phase 7: Final Project Report – Nov 2006
- Phase 8: Generic PoD Handbook – Nov 2006

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Costs

- Total project cost $360 000 (CAD)
  - 40% NRC labour costs covered by NRC and DRDC
  - Costs include, material, equipment, software, design of experiments, crack manufacture, EDM manufacture, travel, fractograghy, reporting and handbook, and 1 reserve NDT Sgt salary
- With more money, I can do more…

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Other PoD work

- NDE Reliability Estimation from technique Development
  - A project funded by Defence Research and Development Canada (DRDC)
  - Purpose is to include a small PoD study with each technique development
  - The study is to be based upon a few defects measured by a few techs resulting in a PoD curve (not statistically sound)
  - a_{NDT} as determined from the PoD will then be multiplied by a safety factor (statistically sound?)
  - PoD modelling?

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Conclusion

- At the completion of the PoD study the minimal detectable crack size (a_{NDT}) in fastener holes using RBHEC will be determined
- Interpolation to other similar structures can be done by applying eddy current models to the PoD results
- This effort will be coordinated by ATESS and involve other CF NDT facilities, NRC, QETE and possible CF contractors

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Acknowledgements

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- National Research Council of Canada for providing the manufactured specimens, design of experiments, statistical analysis, application handbook, and SLAP database analysis
- David Forsyth for his mentorship

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Questions/Feedback/ Comments