ADVANCED LIGO SUSPENSIONS
LSC-Virgo Meeting, Hannover
22nd - 25th October 2007

Suspensions/Isolation Working Group Parallel Sessions

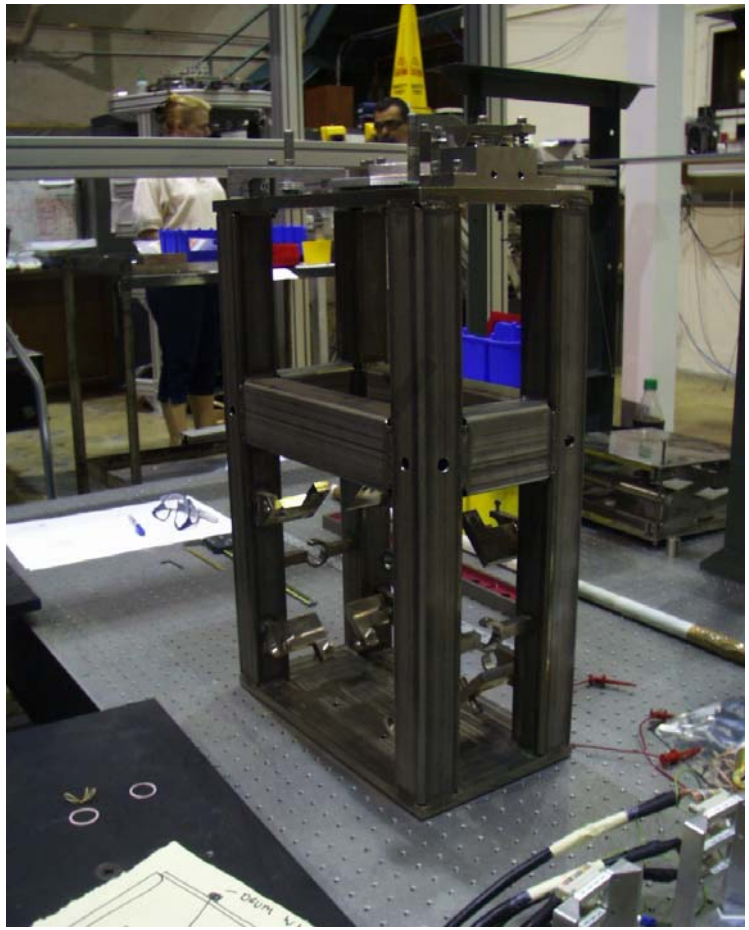
Welding Experiences: Output modecleaner and Recycling Mirror designs

Calum I. Torrie on behalf of ALIGO US Suspension teams

http://lhocds.ligo-wa.caltech.edu:8000/advligo/UHVWelding & LIGO-T070190

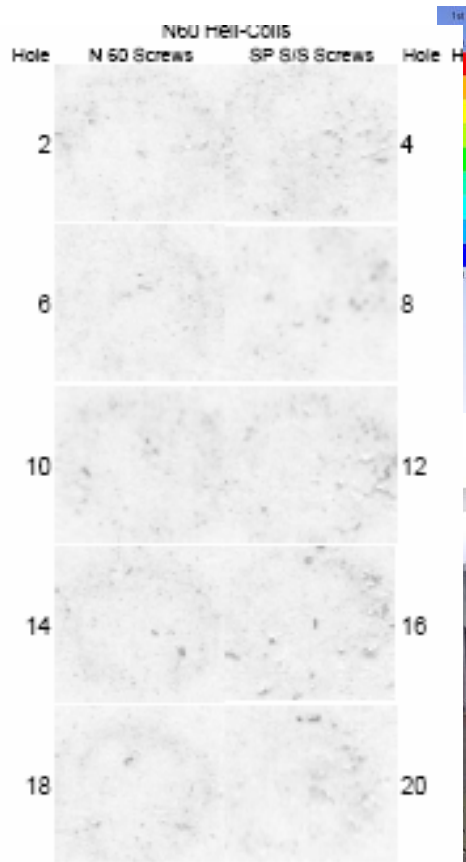
Welding in LIGO

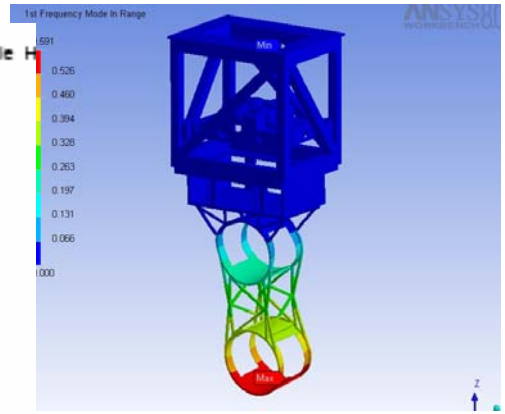
- Examples
  - LIGO I has history of welding stainless and Alum
    - e.g. LOS structure
  - HAM-SAS
    - aluminum (5083) welding practice & experience: LIGO-T060109
  - ALIGO UK (RAL)
- Why?
  - To meet LIGO Vacuum requirements
    - e.g. trapped contaminants could leak out!
  - Stiffness Not strength!



Why not use bolted structures?

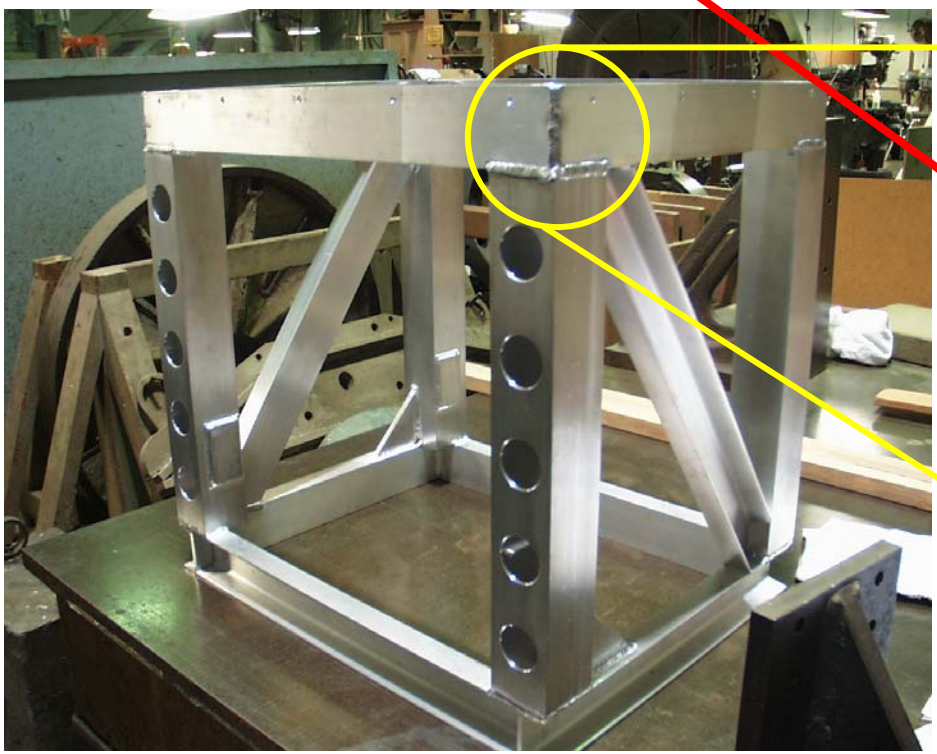
- Yes in principle could use bolted structures to achieve stiffness, but
  - History of problems!
  - Access
  - Ease of assembly
  - Bolts
    - Galling + Debris
      - Ref LIGO-T040111 by L. Jones & C. Torrie

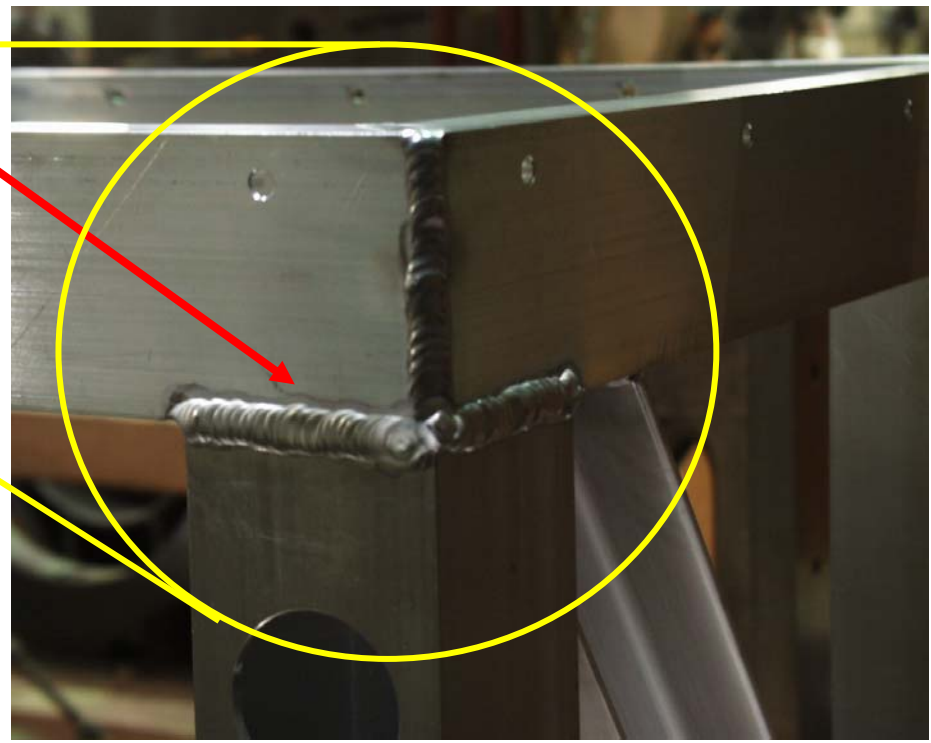




LASTI: Quad Controls prototype

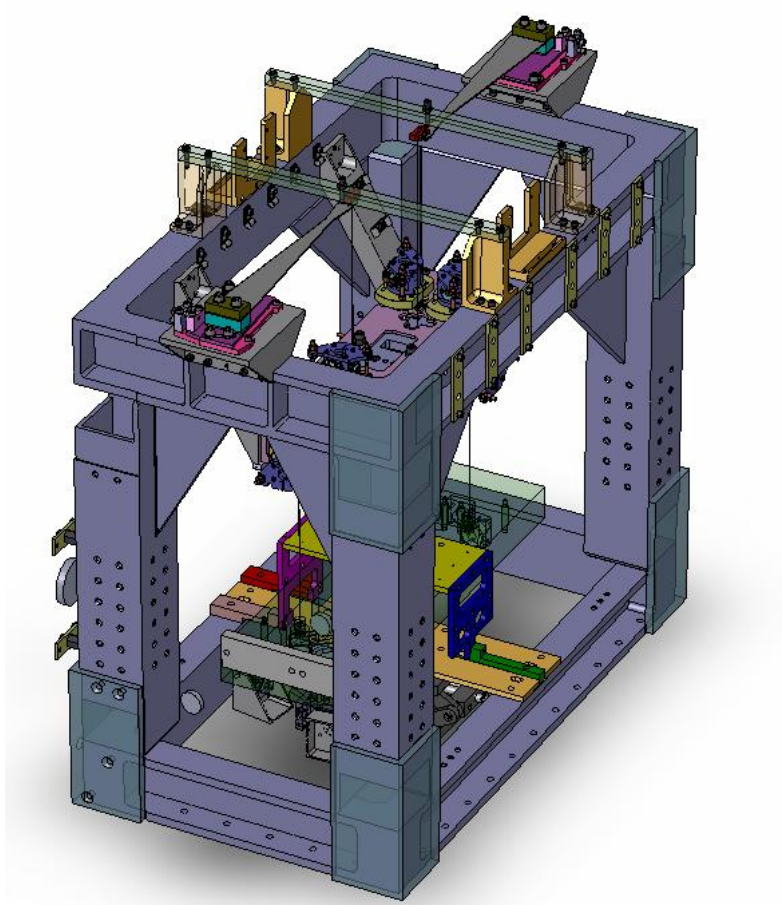
LASTI: Quad Controls prototype – samples, discussions with welder + visual inspection



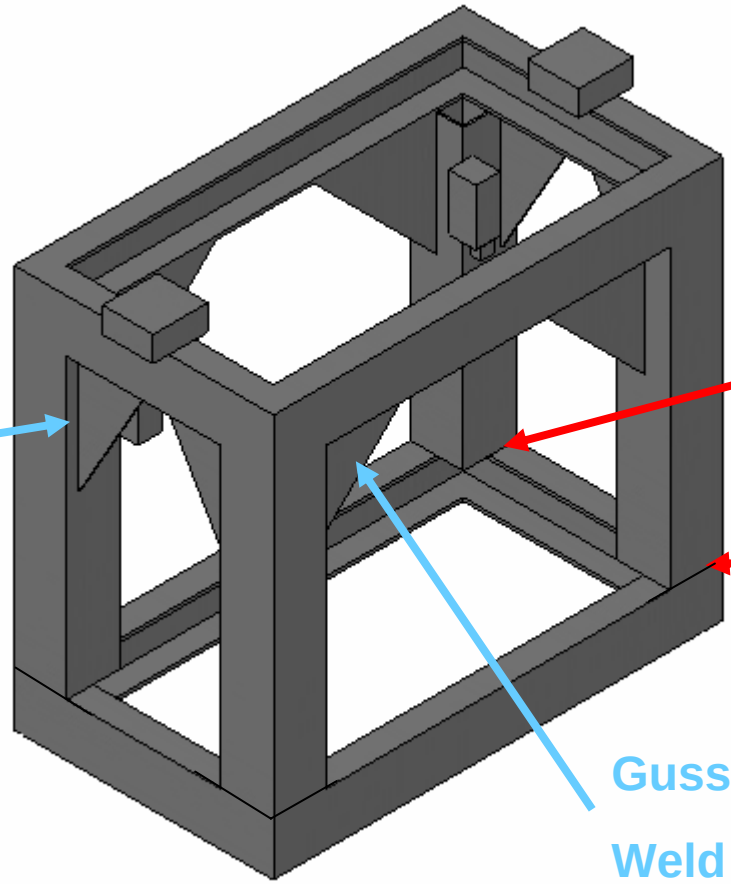


OMC Suspension eLIGO & AdLIGO

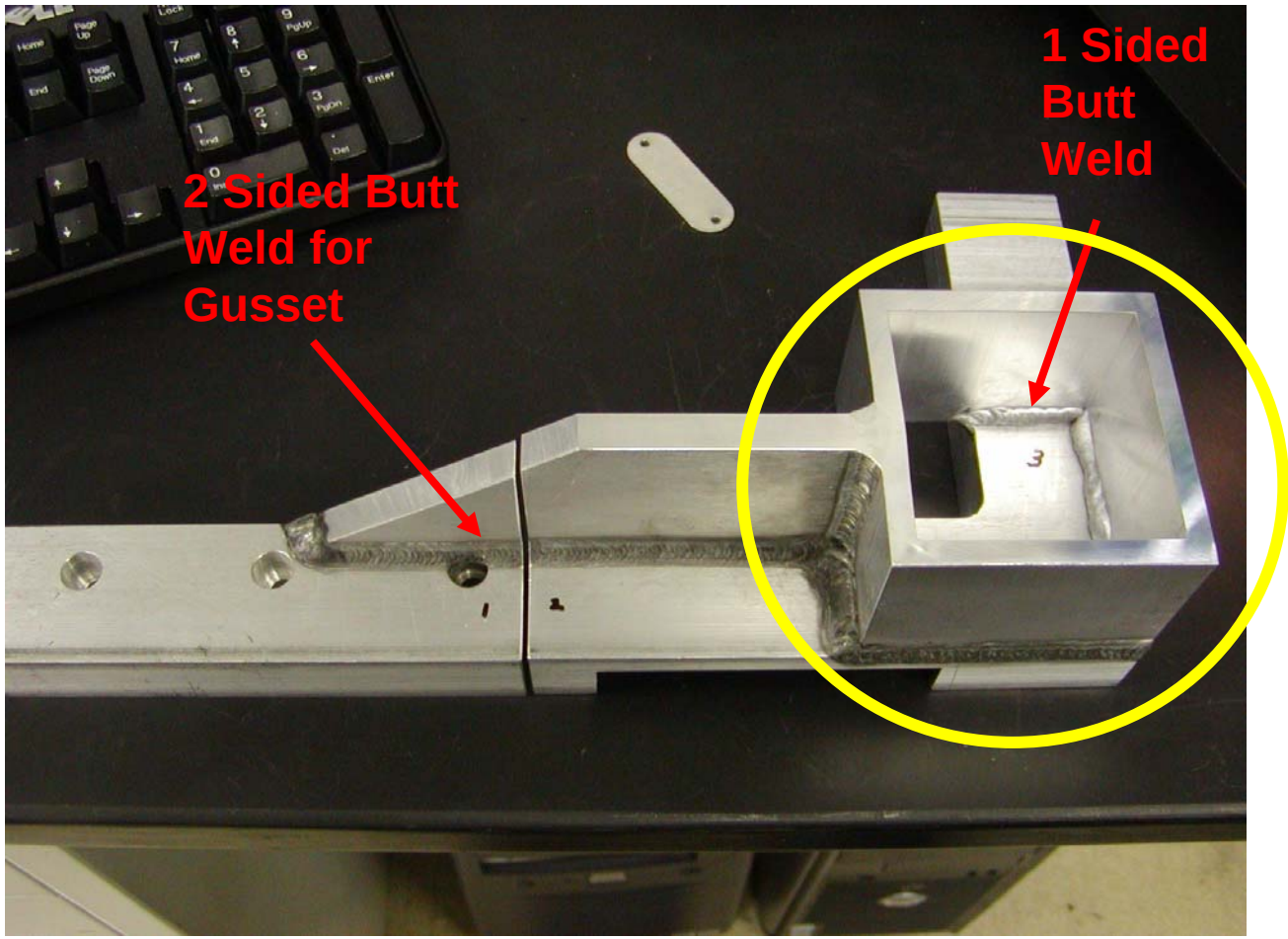
- Why Alum?
  - Design history, had existing design from Quad structure
  - Mass Budget
  - Easy to mount non-suspended components during “metal” assembly
  - ➢ However wanted to better understand welds!



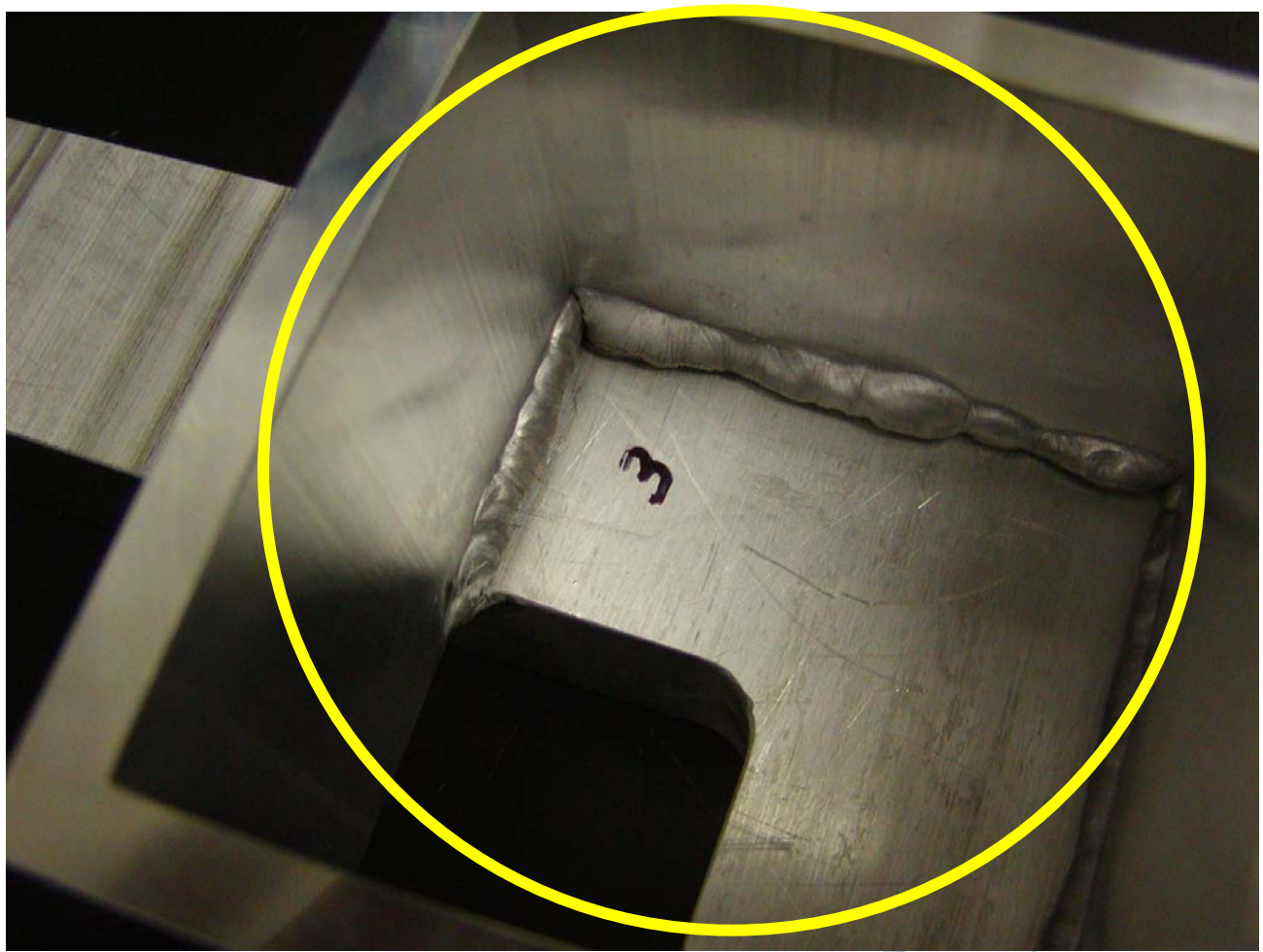
OMC – Original concept



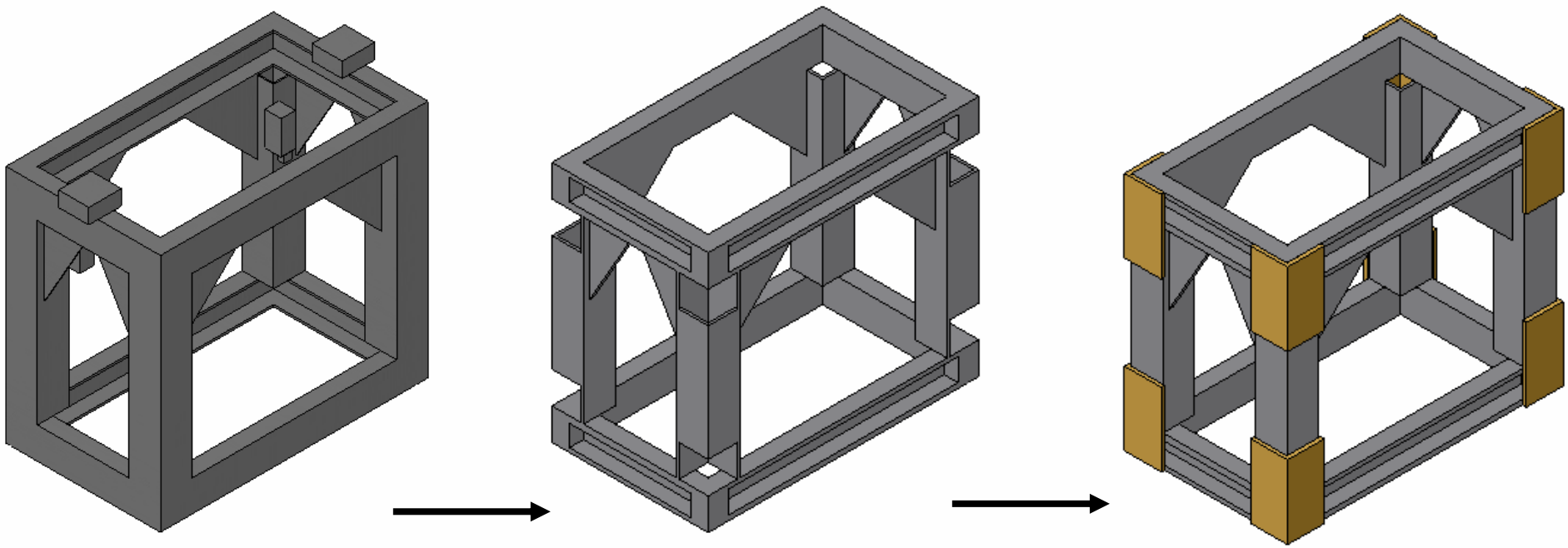
Caltech 1st Alum weld sample for OMC suspension



Inside Caltech 1st Alum weld sample

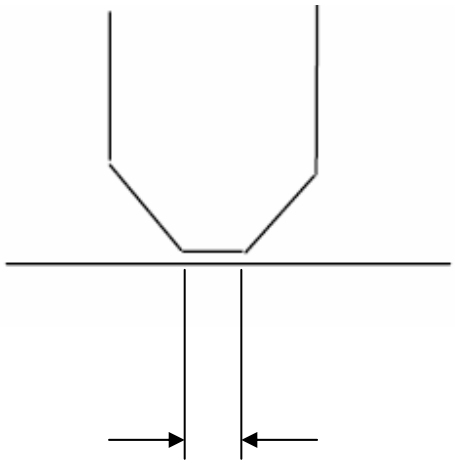


OMC Structure #1



Structure design and analysis: **LIGO-T070205**

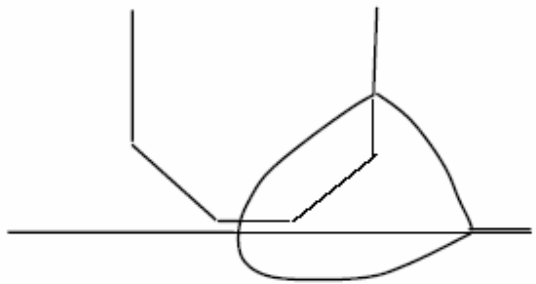
Welds & Welding

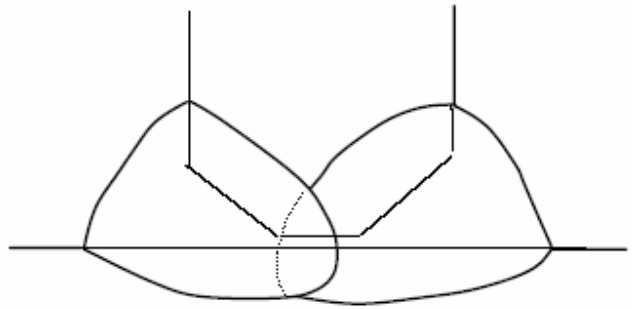


Land

~ 0.039”

[1mm]

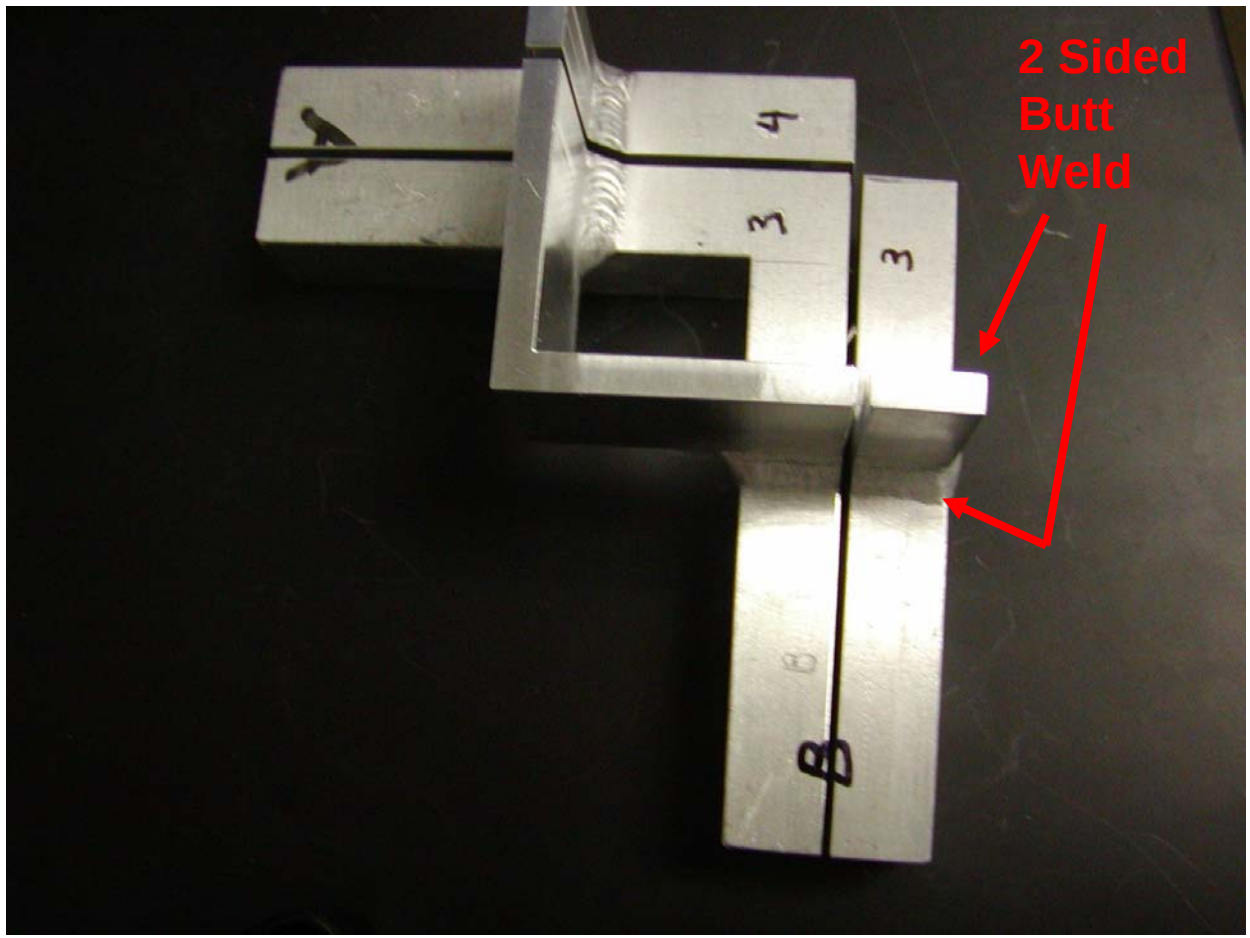




- Tungsten Inert Gas (TIG) welding
  - manual welding process
  - Tungsten electrode,
  - inert gas and a separate filler material
  - ➢ high quality welds but it requires significant operator skill!

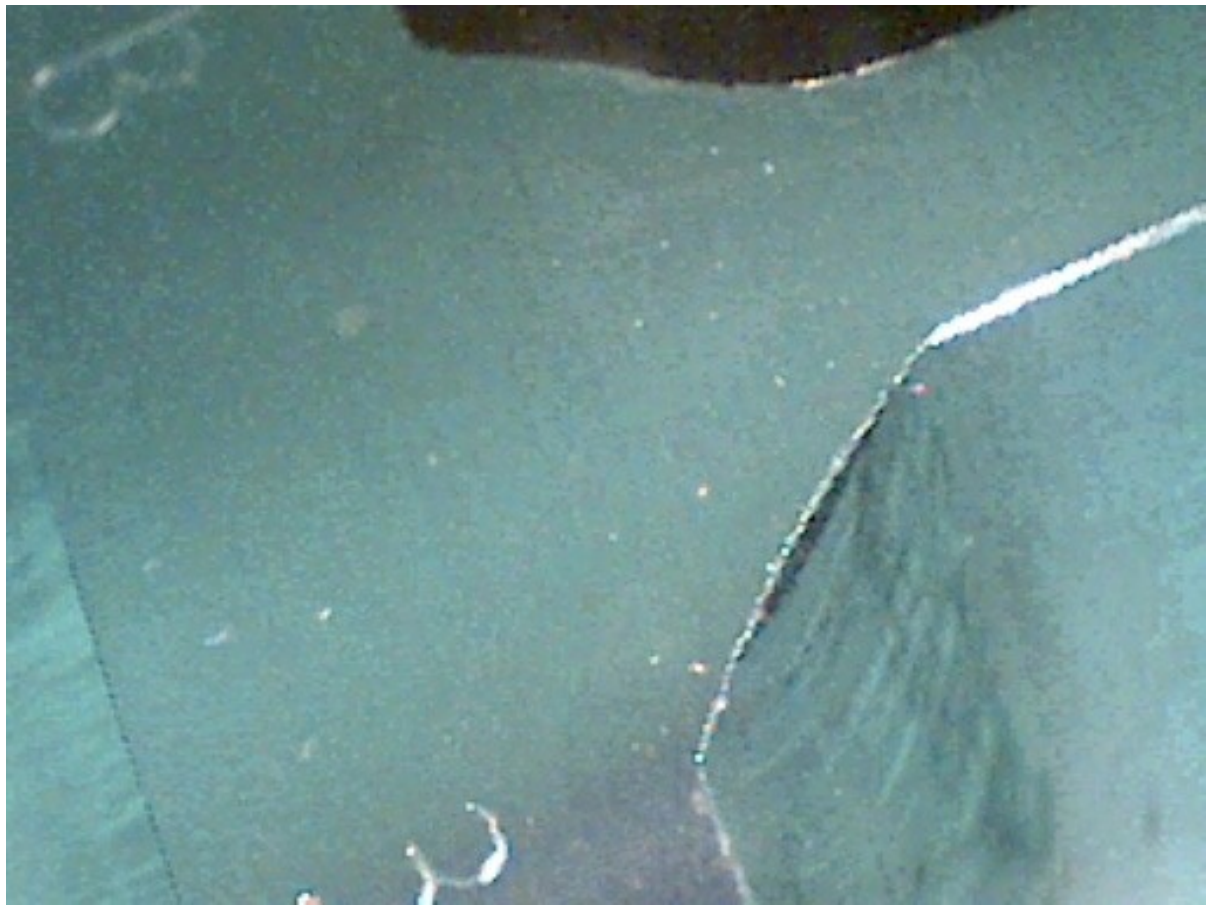
LIGO-T070230

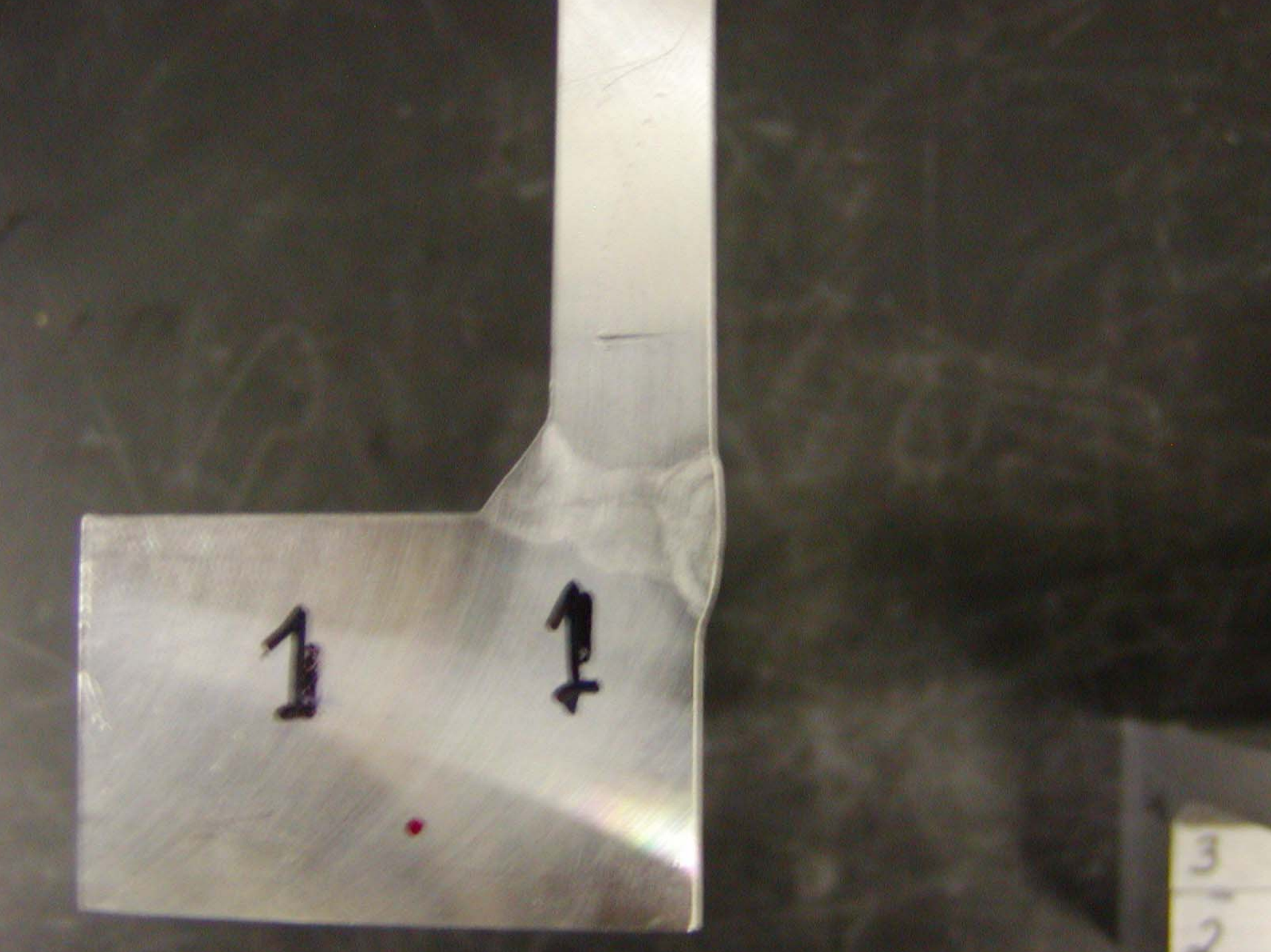
Caltech 2nd Alum weld sample for OMC suspension



Inside Caltech 2nd sample at B3

- Sample cut polished, photographed and viewed under 10x magnification
- Visual inspection
  - Good!
- Further tests
  - refer to later slides

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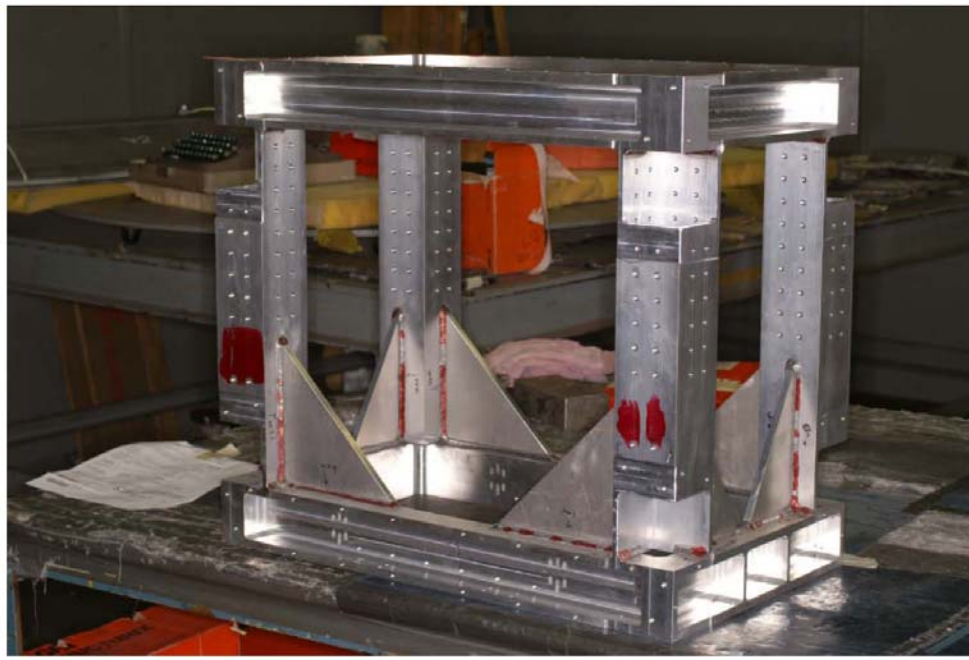
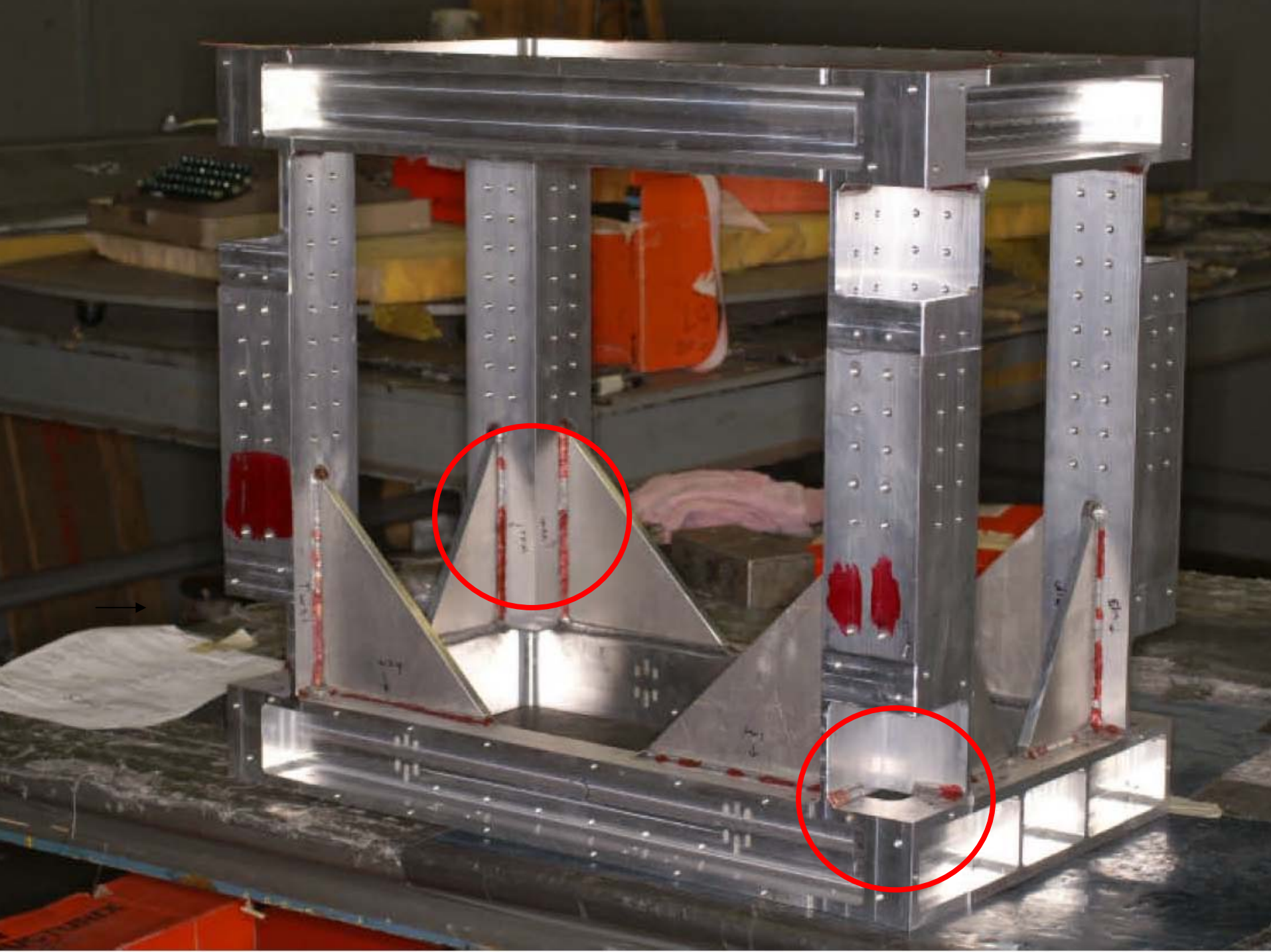
X Rays

- X Ray tests of butt welds carried out with local contractors
  - Base & leg
  - Gusset
- Each weldment radiographed using two different exposures to ensure optimal inspectability





General Testing & Inspection
8427 Atlantic Ave. Cudahy, CA 90201

Submitted To:
KASHAR TECHNICAL SERVICES,INC.
5117 S.CORNING AVENUE
LOS ANGELES, CA 90056

Fax No.:

P.O. No.: KTS JOB 2594
Certification Date: 10/3/2007 1:51:1
Certification No.: 57280
Tag No.: 57281

CERTIFICATE OF PROCESSING

QTY RECEIVED: 6
PART NO.: WELDED FRAME/WELDED SECTIONED PIECES
MATERIAL: 6061 T6 ALUMINUM
DESCRIPTION: 1 PC WELDED FRAME, 5 PC WELDED SECTIONED PIECES

Process	Qty Inspected	Qty Accepted	Qty Rejected	Date Completed	Inspec
Radiography	6	1	5	10/3/2007	A. M

Alice Meza, Level II

X-RAY INSPECT ALL WELDS PER ASTM E1742-06* MIL-STD-2219A
CLASS A

TOTAL ACCEPTED: 1 TOTAL REJECTED: 5

Respectful

Denise Wh
Quality Ad

Nadcap
NDT / ETCH

Inspectors are certified IAW SNT-TC-IA / NAS 410/Level II (as required). Parts have been processed IAW applicable specifications as indicated. Our Liability per part is limited to a maximum of 5 times the processing charge per part

General Testing & Inspection

REPORT - WE

NO. 57280 SHEET 2

CUSTOMER: KASHAR TECHNICAL DATE: 10-02-07

PART NO.: WELDED FRAME/WELDED SECTIONED PCS. SN:

Description	ACC	REJ	RP	LP	GH	CR	NF	FMLD	FMMD	IP	UC	SUR	Remarks
S/N- 1													
W1		X	X		X		X						.130 SPACING
W2		X	X		X								.085 SPACING
W3		X	X		X		X						.085 SPACING
W4		X	X		X								.085 SPACING
W5		X	X										SPACING
W6		X	X				X						SPACING
W7		X	X				X						SPACING
W8		X	X				X						SPACING
W9		X	X										
W10		X	X		X		X						.125 SPACING
W11		X	X										SPACING
W12		X	X				X						SPACING
W13		X	X										SPACING
W14		X	X										SPACING
W15		X	X				X						SPACING
W16		X	X				X						SPACING
W17		X	X				X						SPACING
W18		X	X				X						SPACING
W19		X	X										SPACING
W20		X	X		X		X						SPACING
W21		X			X								.100
W22		X	X		X								SPACING, .125
W23		X	X				X						SPACING
W24		X	X		X								SPACING
W25		X			X								SPACING
W26		X	X										SPACING
W27		X	X		X								.125 SPACING
W28		X	X		X								SPACING
W29		X	X		X		X						.125 SPACING
W30		X	X										SPACING
W31		X	X		X								.190 SPACING
W32		X	X										SPACING
W33	X		✓										
W34		X	X										SPACING
W35		X	X		X								.110 SPACING
W36		X	X		X								SPACING
W37		X	X				X						SPACING
W38		X	X		X								SPACING
W39		X	X		X								.150 SPACING
W40		X	X										SPACING

LEGEND: RP=Round Porosity LP=Line Porosity GH=Gas Hole CR=Crack NF=Non-Fusion FMLD=Foreign Material Less Dens
FMMD=Foreign Material More Dense IP=Incomplete Penetration UC=Undercut SUR=Surface

NOTES:

INSPECTOR A. MEZA LEVEL II DATE 10-3-07

SOURCE INSPECTION BY DATE

Welding terms in the X-ray Inspection Report

- Porosity
  - Formed by gas entrapment during solidification
  - ➢ LIGO seeks low porosity!
- Crack
  - Fracture type discontinuity

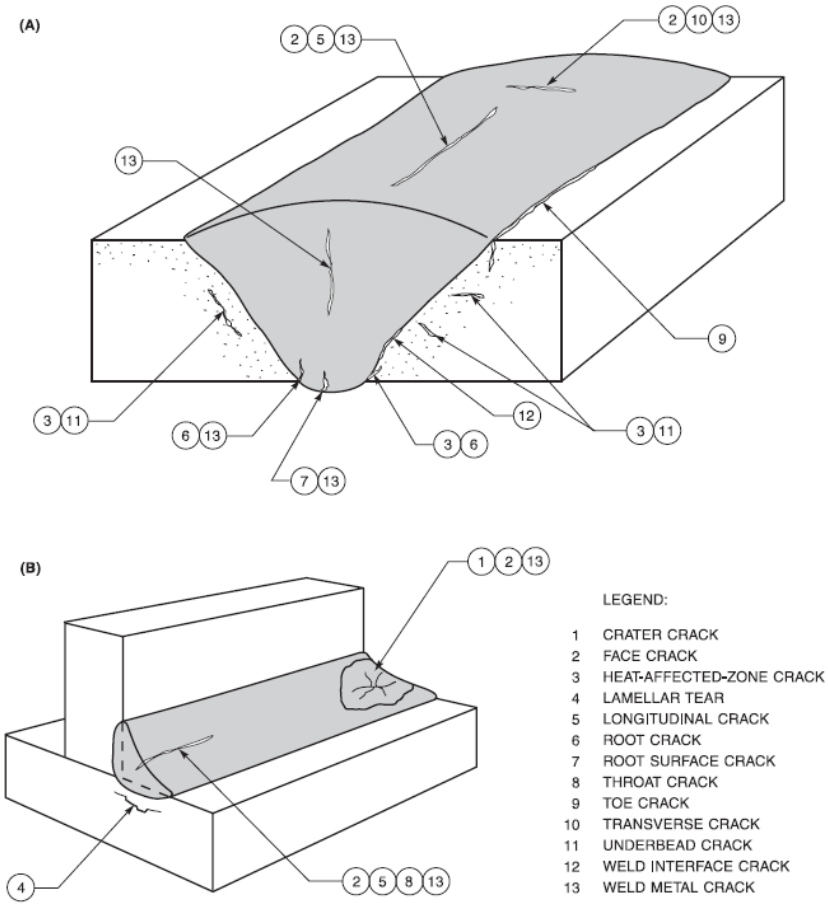


Figure 33—Crack Types

General Testing & Inspection
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Alice Meza, Level II

X-RAY INSPECT ALL WELDS PER ASTM E1742-06* MIL-STD-2219A
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Respectful

Denise Wh
Quality Ad

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General Testing & Inspection

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W2		X	X		X								.085 SPACING
W3		X	X		X		X						.085 SPACING
W4		X	X		X								.085 SPACING
W5		X	X										SPACING
W6		X	X				X						SPACING
W7		X	X				X						SPACING
W8		X	X				X						SPACING
W9		X	X										
W10		X	X		X		X						.125 SPACING
W11		X	X										SPACING
W12		X	X				X						SPACING
W13		X	X										SPACING
W14		X	X										SPACING
W15		X	X				X						SPACING
W16		X	X				X						SPACING
W17		X	X				X						SPACING
W18		X	X				X						SPACING
W19		X	X										SPACING
W20		X	X		X		X						SPACING
W21		X			X								.100
W22		X	X		X								SPACING, .125
W23		X	X				X						SPACING
W24		X	X		X								SPACING
W25		X			X								SPACING
W26		X	X										SPACING
W27		X	X		X								.125 SPACING
W28		X	X		X								SPACING
W29		X	X		X		X						.125 SPACING
W30		X	X										SPACING
W31		X	X		X								.190 SPACING
W32		X	X										SPACING
W33	X		✓										
W34		X	X										SPACING
W35		X	X		X								.110 SPACING
W36		X	X		X								SPACING
W37		X	X				X						SPACING
W38		X	X		X								SPACING
W39		X	X		X								.150 SPACING
W40		X	X										SPACING

LEGEND: RP=Round Porosity LP=Line Porosity GH=Gas Hole CR=Crack NF=Non-Fusion FMLD=Foreign Material Less Dens
FMMD=Foreign Material More Dense IP=Incomplete Penetration UC=Undercut SUR=Surface

NOTES:

INSPECTOR A. MEZA LEVEL II DATE 10-3-07

SOURCE INSPECTION BY DATE

Welding terms in the X-ray Inspection Report

- Non-Fusion (NF)
  - a weld discontinuity in which fusion did not occur between weld metal and fusion faces or adjoining weld beads

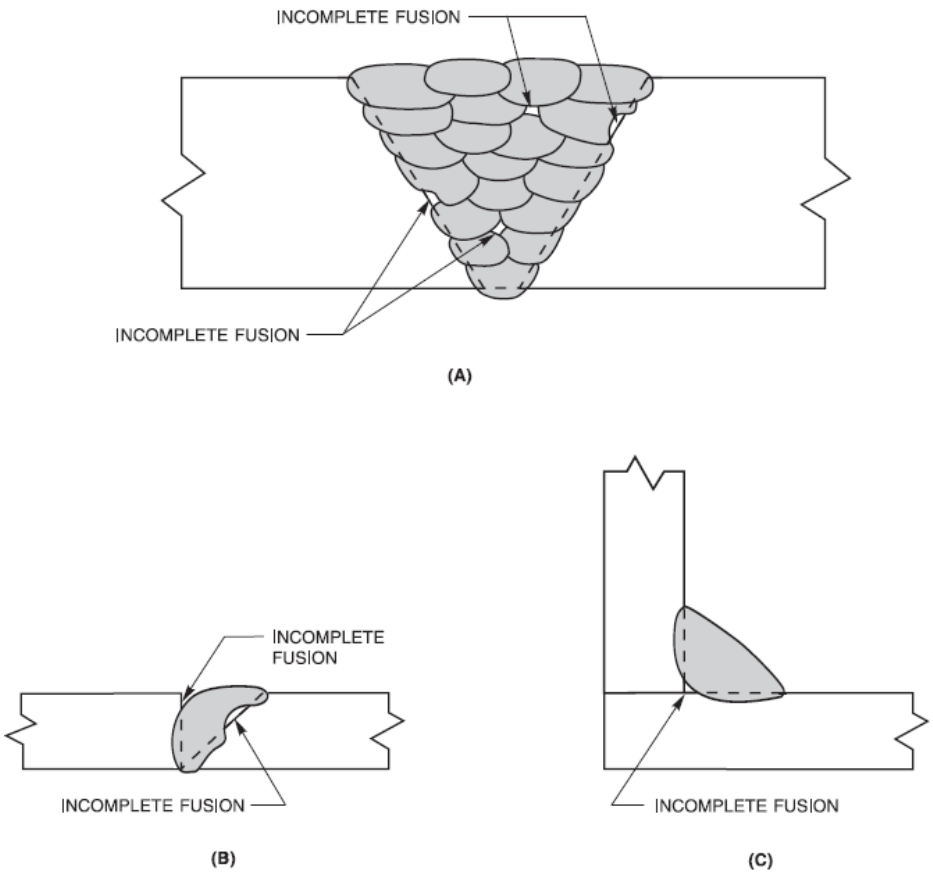


Figure 29—Incomplete Fusion

OMC Test Results

- On the OMC structure, only 3 welds were found to be acceptable per MIL-STD-2219 Class A
- Most of the OMC weldments would not meet Class B because of very large porosity and / or excessive closely spaced porosity.
- 20 of the 56 OMC weldments would not meet the requirements for Class C because of their lack of fusion.

X Rays

- Met to discuss X Rays
  - "How many of the 20 welds that show no fusion are buried inside and how many are through to the surface?"

➢ Inconclusive!

➢ Maybe this is good news!

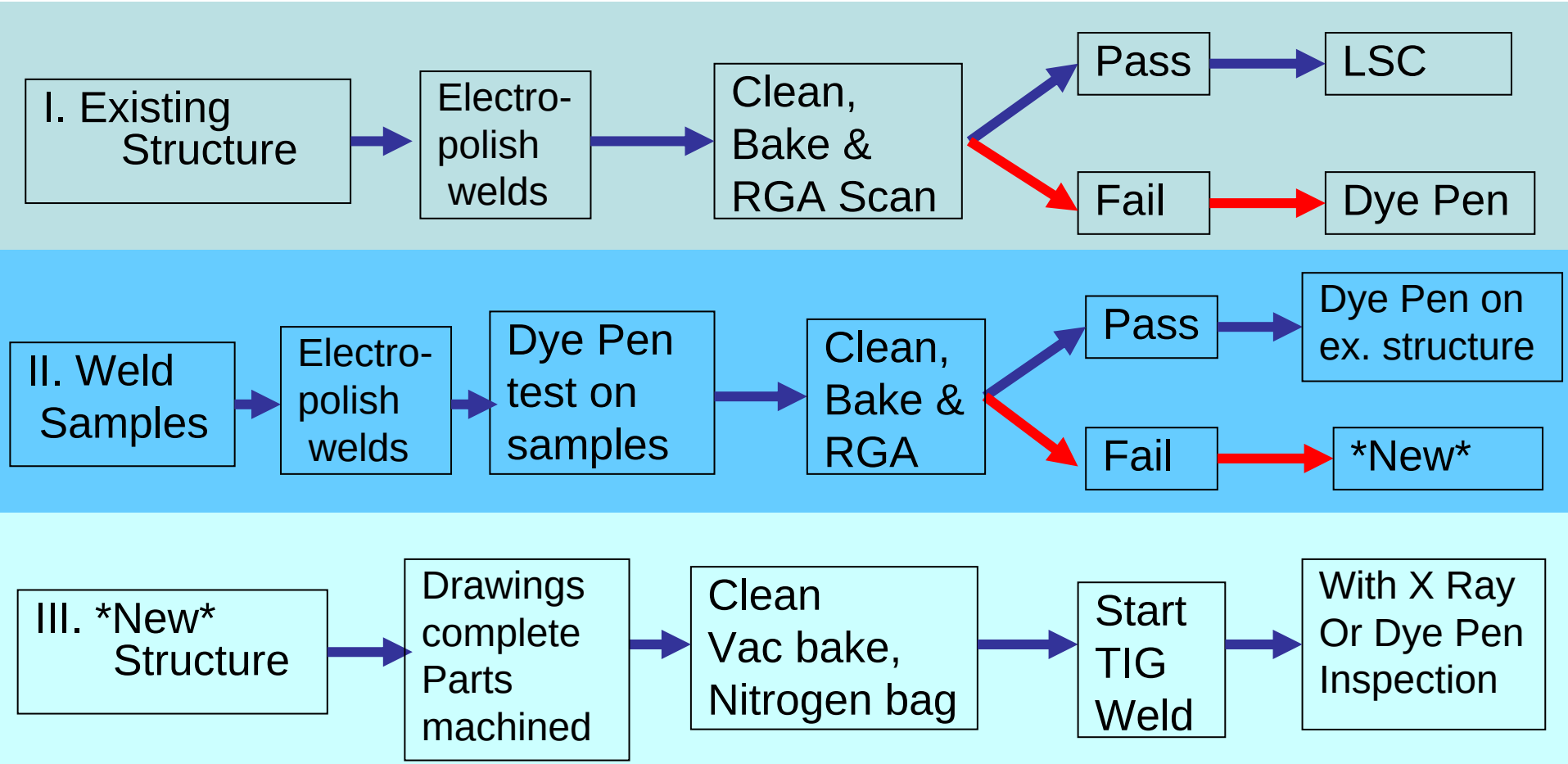
Add image from Bob

➢ So came up with a 3 point plan!

Still waiting for results on samples!

Additional samples?

Plan - Chart

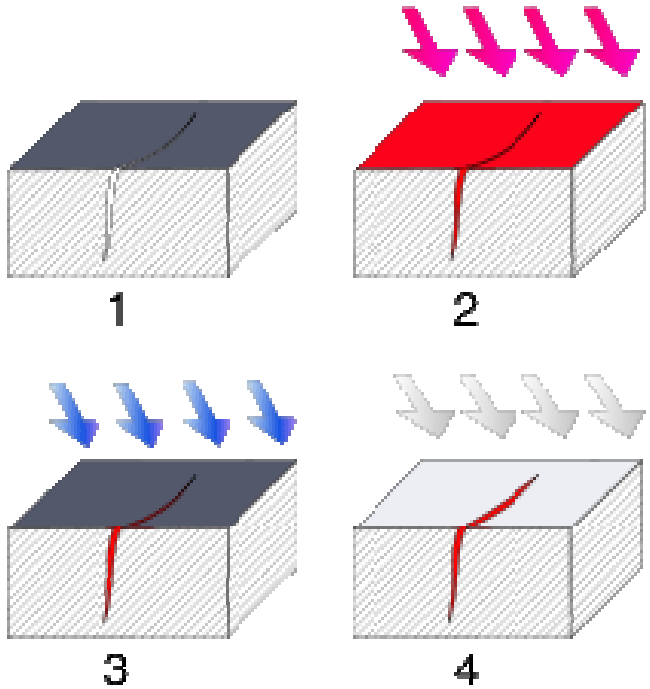


TIMELINE: → **Mid – Oct** → **Mid – Nov** → **Mid – Dec**

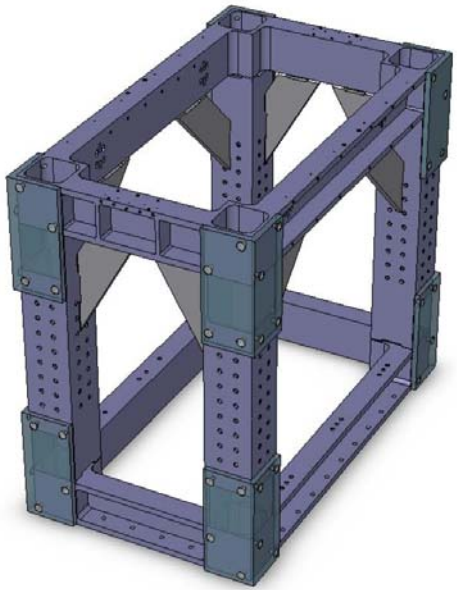
Proposed Dye Penetrant Test

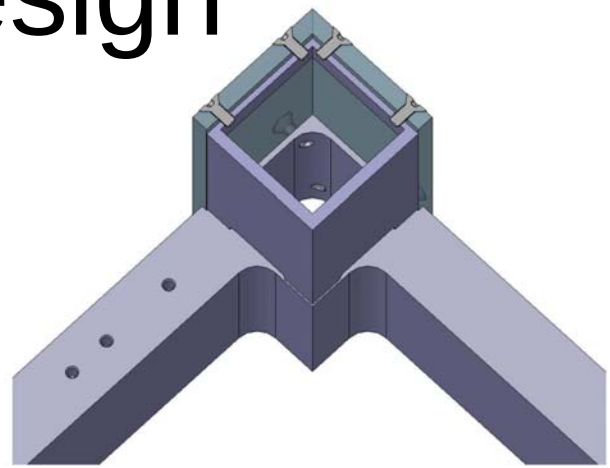
- Section of material with a surface-breaking crack that visible to the naked eye
- Penetrant applied to the surface
- Excess penetrant removed
- Developer applied, rendering the crack visible

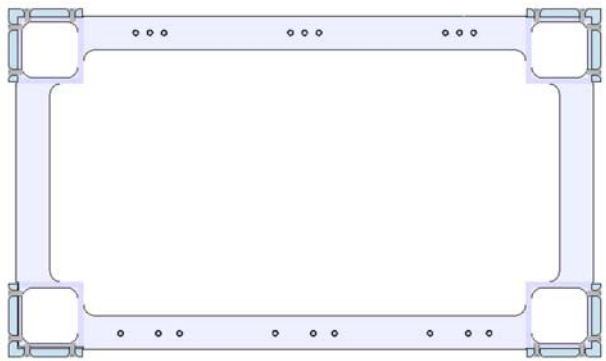
- LIGO Compatible test wrt ability to make structure clean afterwards?
  - Dye Pen
    - Water soluble
- Developer
  - Non-aqueous wet developer
    - Isopropyl Alcohol

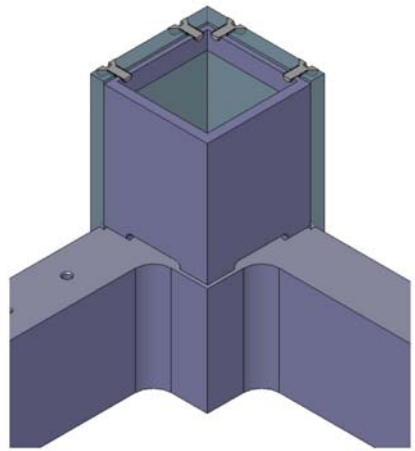


New OMC Design



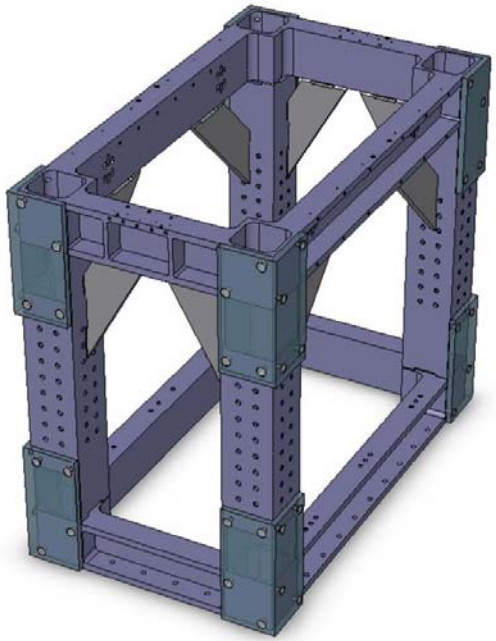


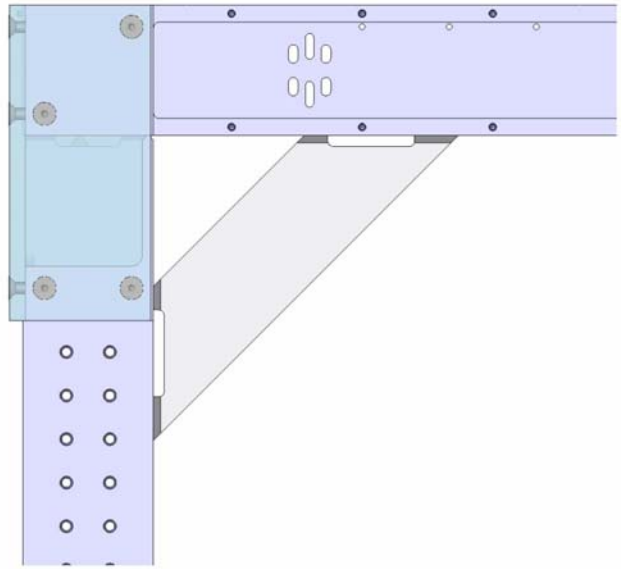


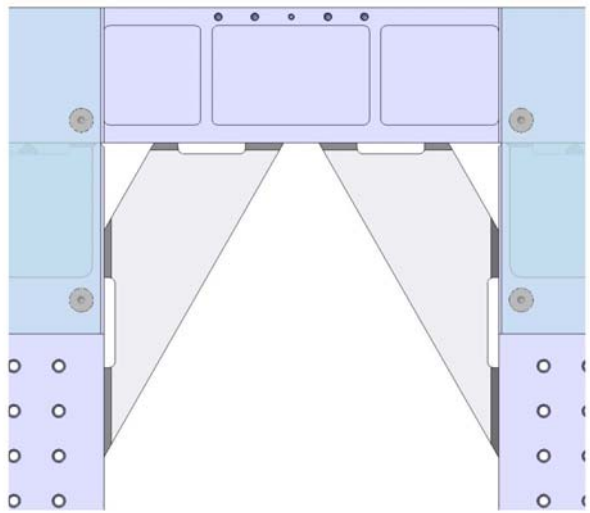


LIGO-D060296

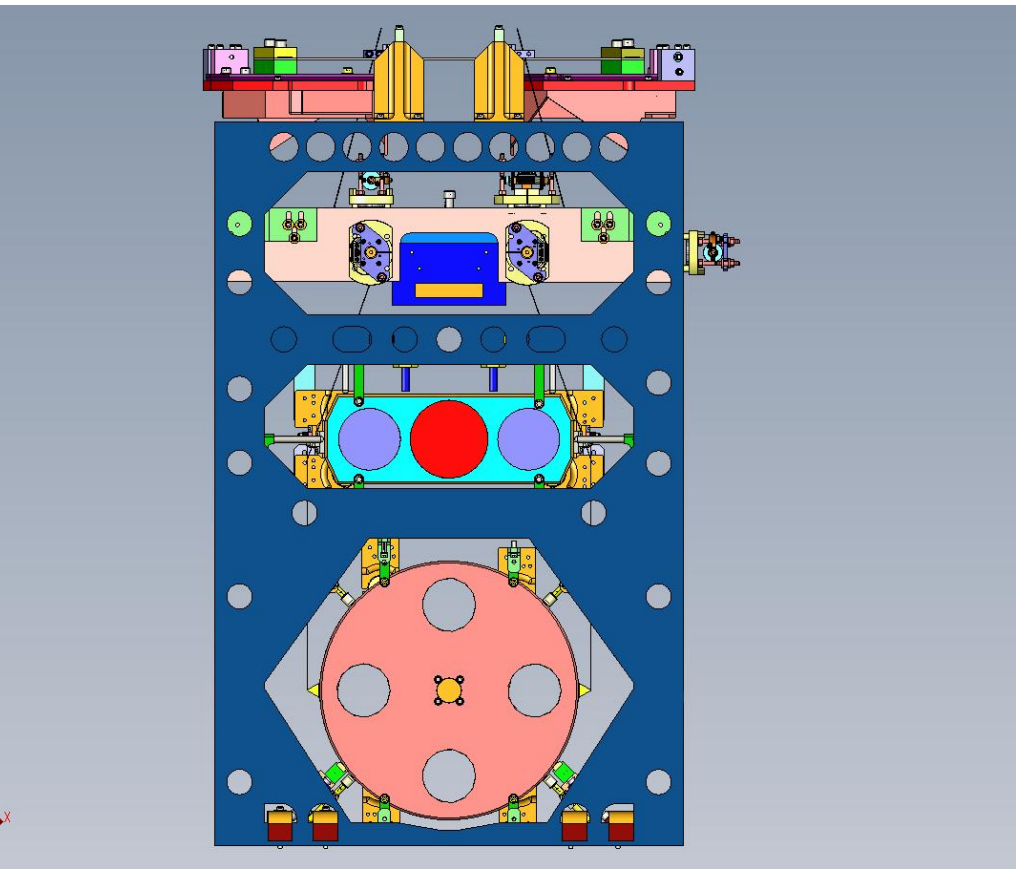
New OMC Design

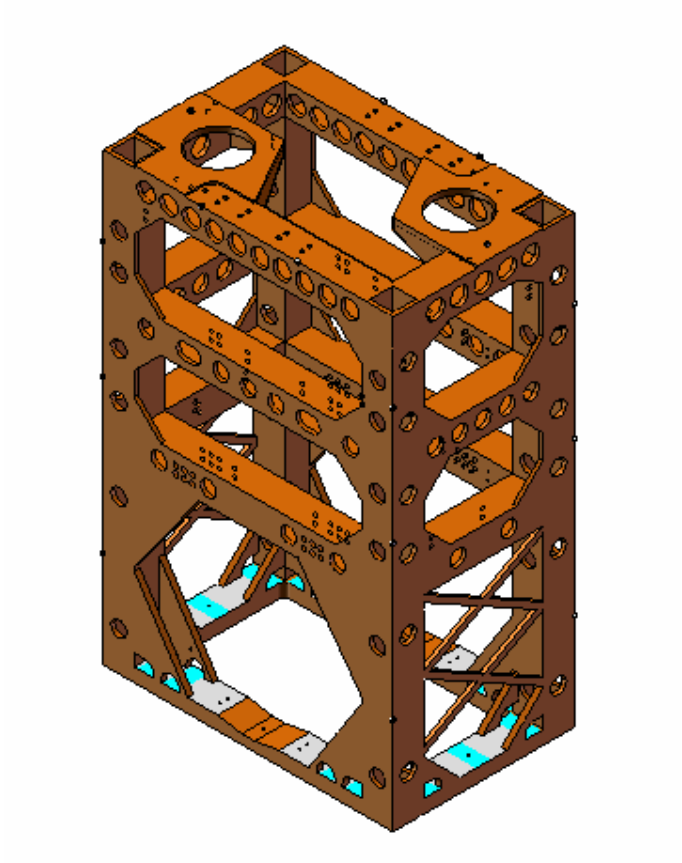






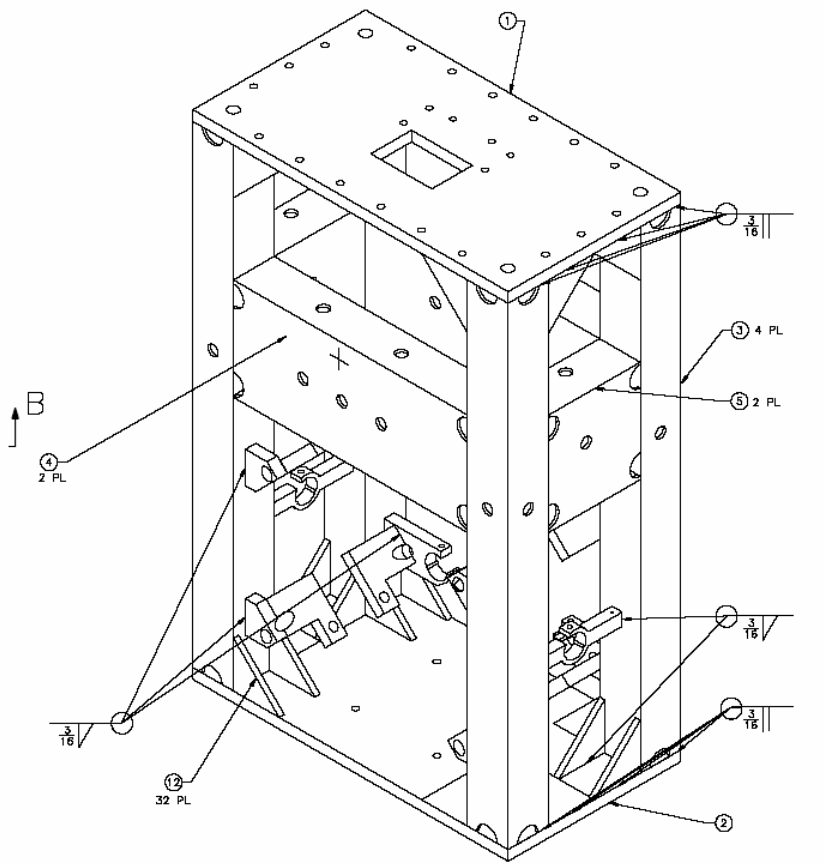
RM Suspension + Structure

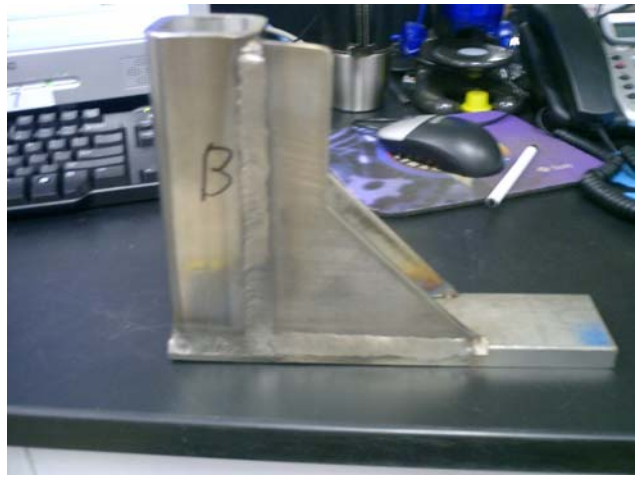




LIGO-T070169 and LIGO-T070238

RM Tests & History





- 304 SSTL Weld Sample
- LIGO I LOS Structure

Conclusions / Outcome

- Idea is that all of this work will lead to ability to better classify welds for Advanced LIGO e.g. class C low porosity no cracks!

- To achieve this probably also consider additional weld samples e.g.
  - To match new OMC design
  - RAL design see picture & previous talk
  - RM design