Development of a Flame Propagation Test Method for Structural Composite Materials in Inaccessible Areas

Federal Aviation Administration

International Aircraft Materials Fire Test Working Group Meeting

June 22-23, 2011, Bremen, Germany

Robert I. Ochs, FAA Fire Safety Team AJP-6322

Introduction

- **Carbon fiber composites are being used more frequently in aerospace applications**
  - Increased strength
  - Lower density
  - Better corrosion resistance

- **New designs of commercial transport airplanes include primary structure constructed from carbon fiber composites**

- **Current FAR's do not require flammability testing for fuselage skins or structures, as traditional designs are inherently non-flammable**

- **To continue with the FAA's efforts to enhance in-flight fire safety, materials in inaccessible areas of the cabin should meet a flammability test based on the "block of foam" fire source**

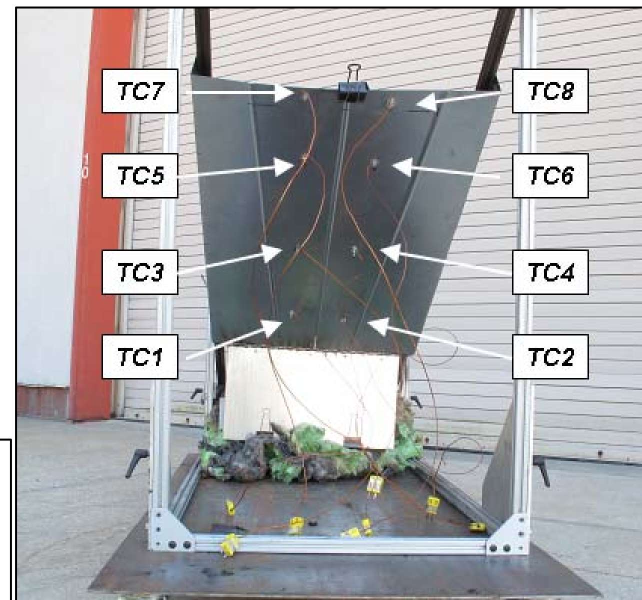
Objective

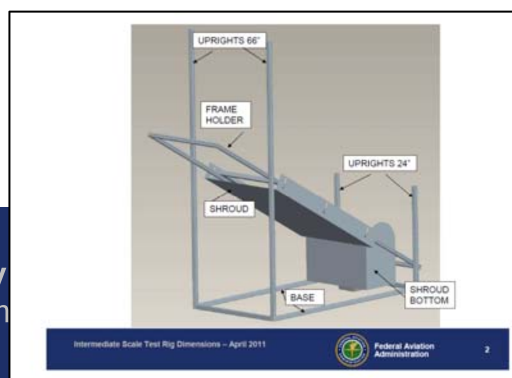
- **Develop a standardized laboratory-scale flammability test method to determine the flame propagation resistance of structural composite materials**

- **Test should correlate with an intermediate-scale test using the block of foam fire source**
  - Thermal/acoustic insulation
  - Ducting
  - Wire insulation

Intermediate Scale Test Rig

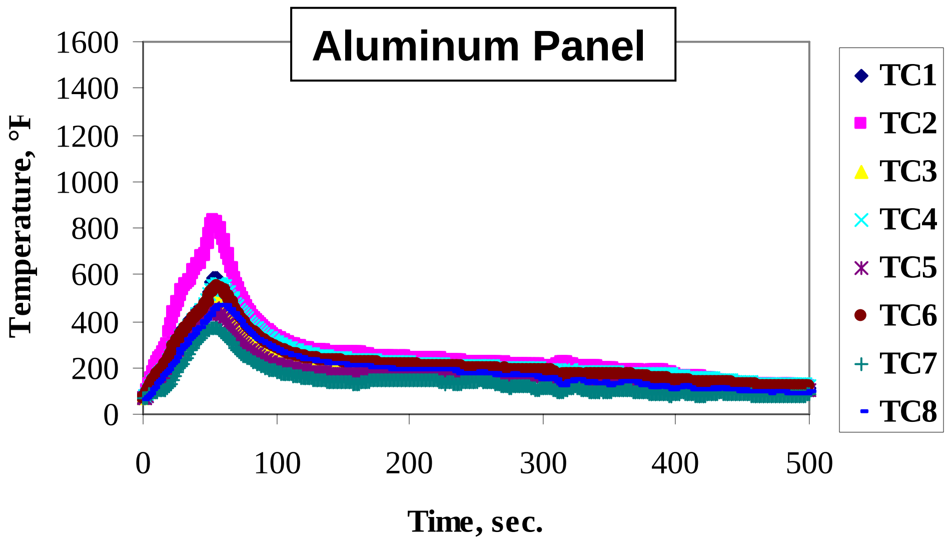
- **A sample holder was constructed to simulate an inaccessible area in an aircraft cabin**
- **Flat panels of composite material were tested due to the high cost of curved panels**
  - Panel dimensions 18”x48”x1/8”
- **The angle of incidence can be varied**
  - 30° chosen for strong flame impingement and buoyancy assisted propagation
- **4” x 4” x 9” untreated urethane foam block fire source**
  - 10 mL heptane soaked into bottom of foam block to promote uniform burning
- **Thermocouples measure inboard panel temperature to assess flame propagation**
- **Plans for construction are now available on KSN site**

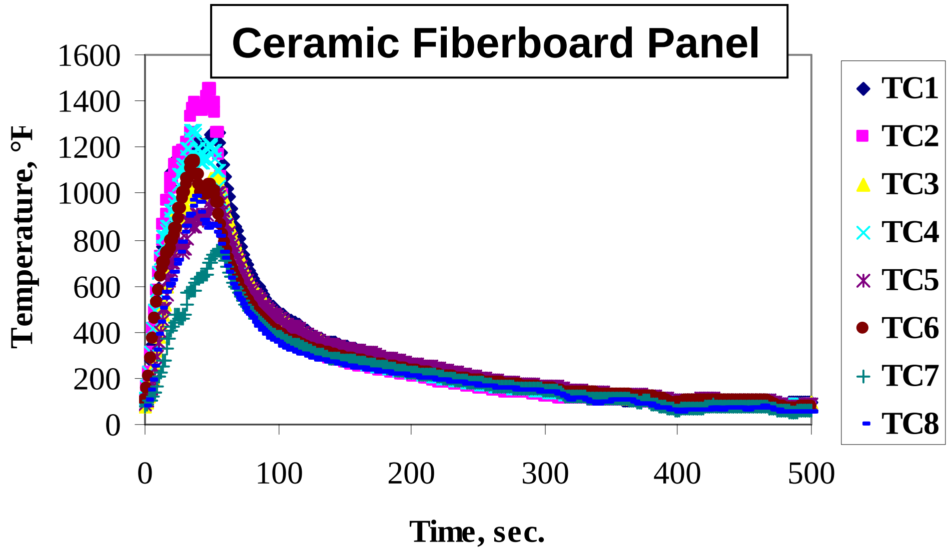




Baseline Test

- Baseline tests were run with panels of aluminum and ceramic fiberboard
- Temperature profiles were measured for duration of foam block burning
- Peak temperature is indicative of conductivity of panel
- Peak width indicates duration of burning event

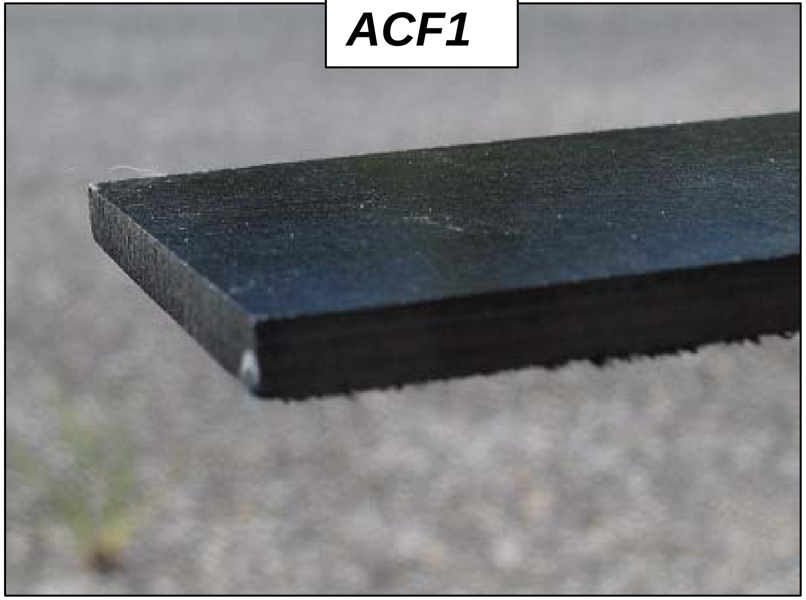




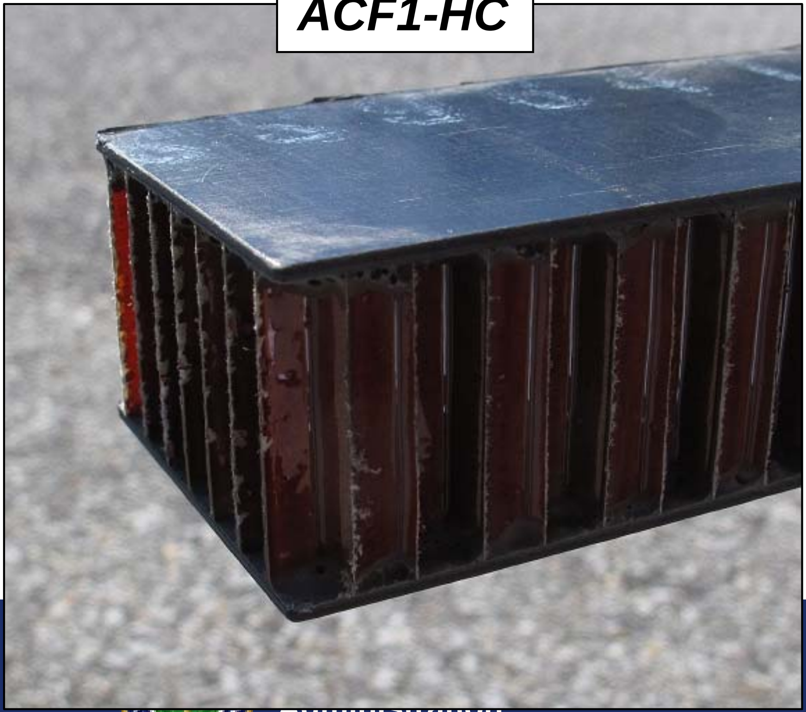
Composite Materials

- **Non-aerospace composites**
  - GAR10: glass-cloth laminate with epoxy resin binder
  - GRP: glass-reinforced polyester sheet
  - FLXCF: flexible fine weave carbon fiber sheet
  - RGDCF: rigid woven carbon fiber sheet
- **Aerospace grade composites**
  - ACF1: carbon/epoxy panel 16 plies unidirectional tape, 320 g/m^2 aerial weight, prepregged with amine cured, toughened 356°F epoxy resin system
  - ACF2: carbon/epoxy panel unidirectional carbon tape, 1.79 g/cm^3 density, prepregged with a toughened, 365°F cure epoxy system
  - ACF3: carbon/epoxy panel woven carbon fabric, 193 g/m^2 aerial weight prepregged with 250°F cure epoxy system
  - ACF1-HC: 4 plies of ACF1 prepreg bonded with film adhesive to both sides of a 1” thick, .25” cell size honeycomb core, total sample thickness 1 1/16”

ACF1



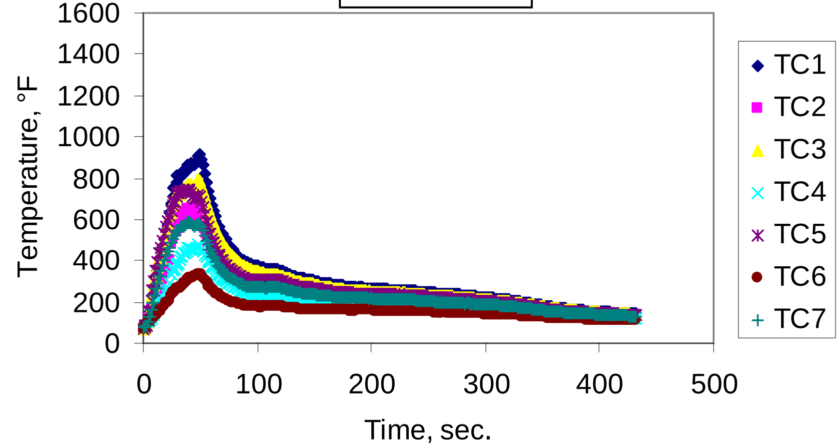
ACF1-HC



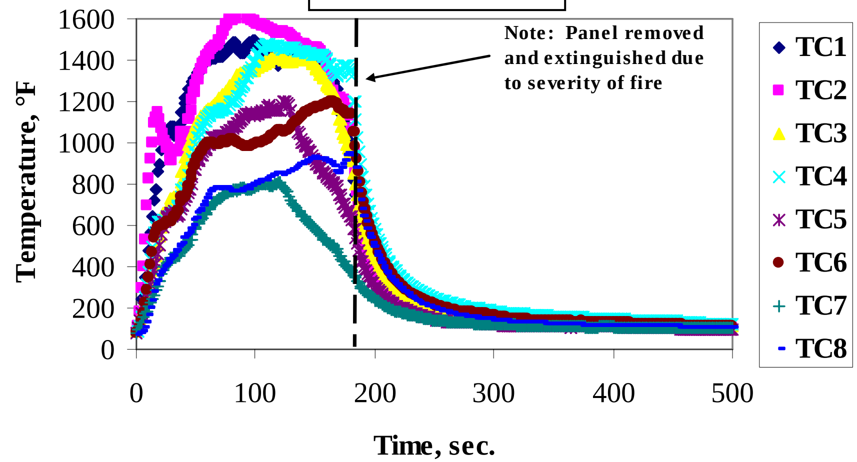
Intermediate Scale Test

ACF1-HC

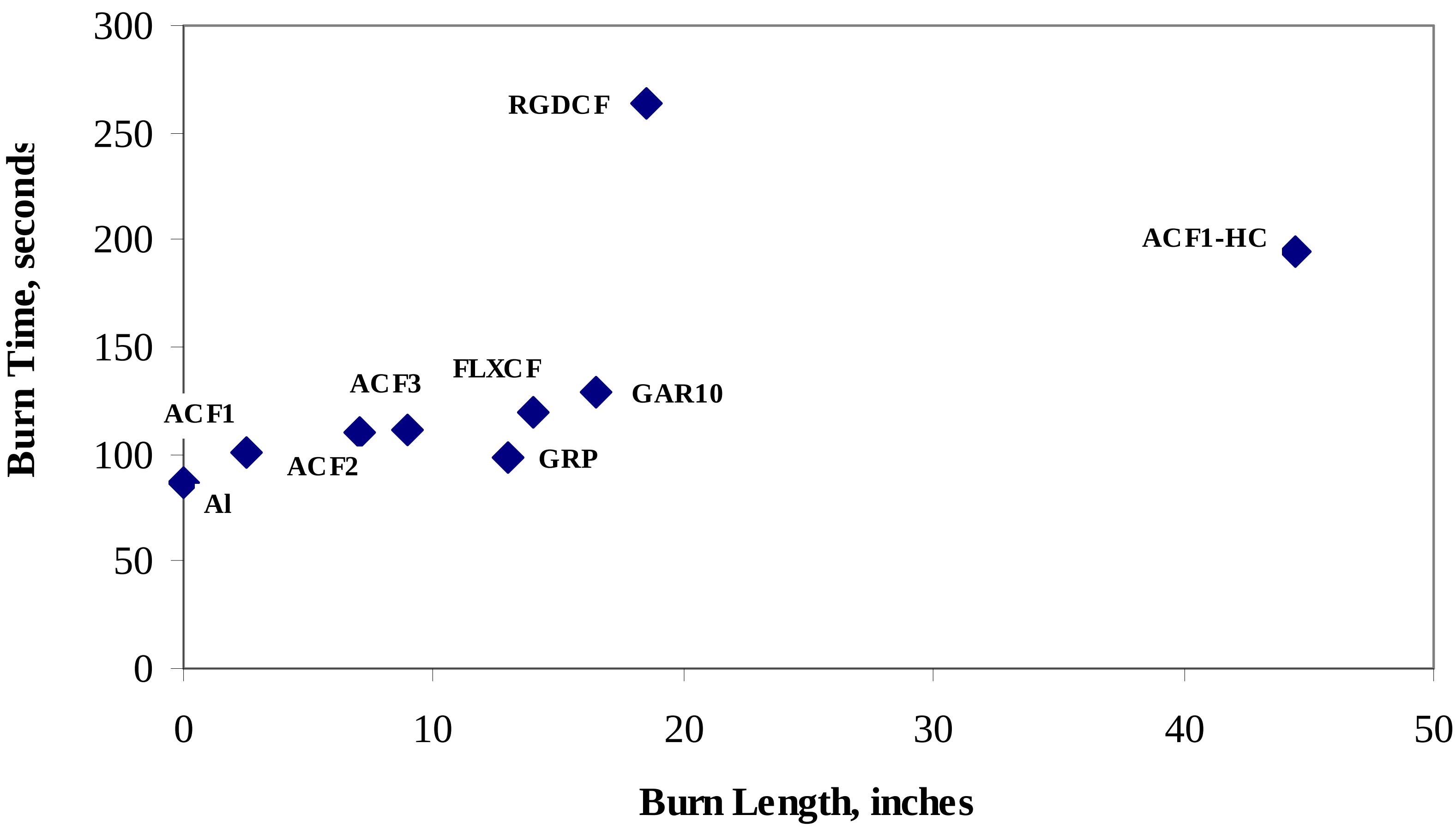
ACF1



ACF1-HC



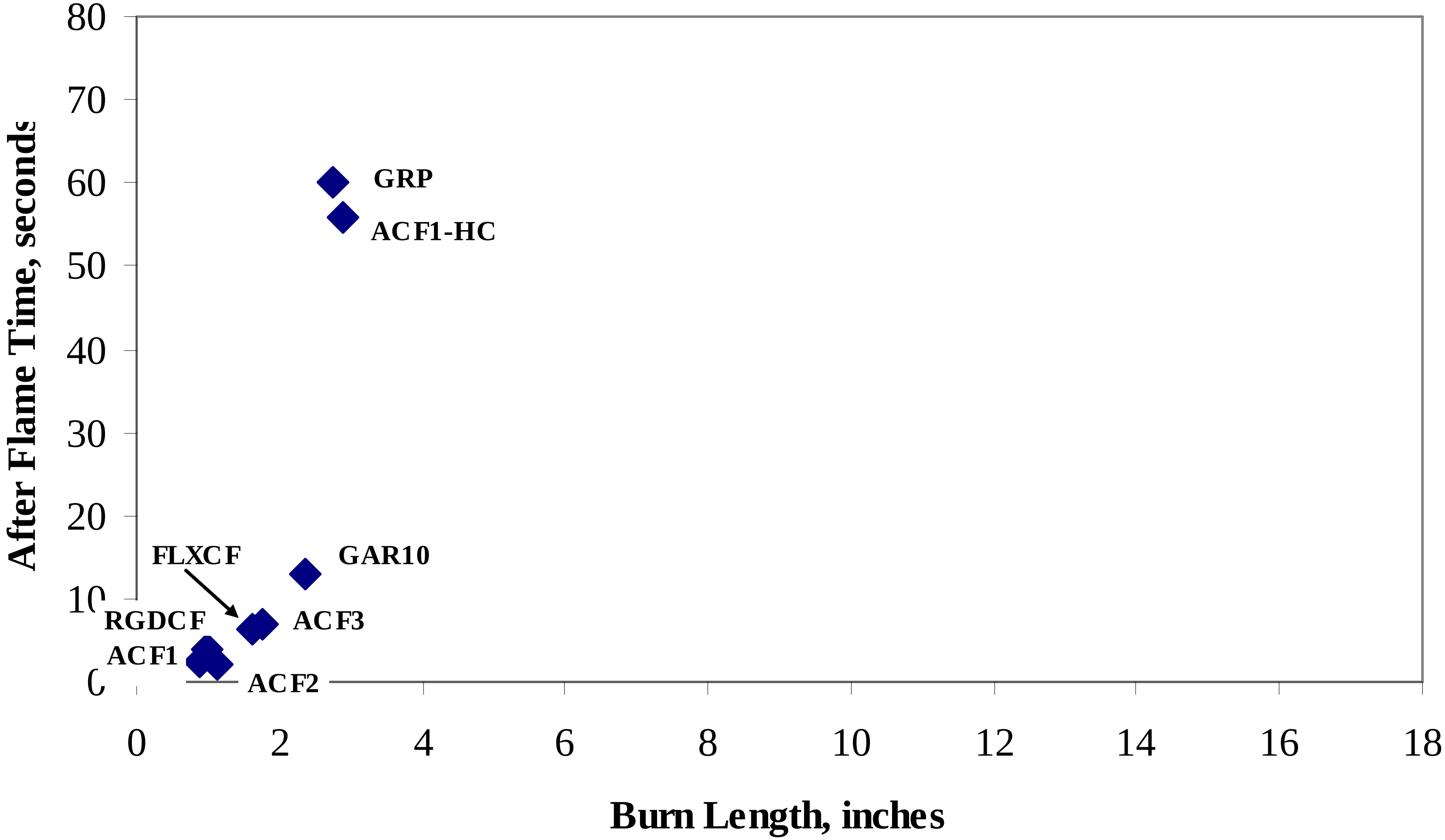
Intermediate Scale Test Results



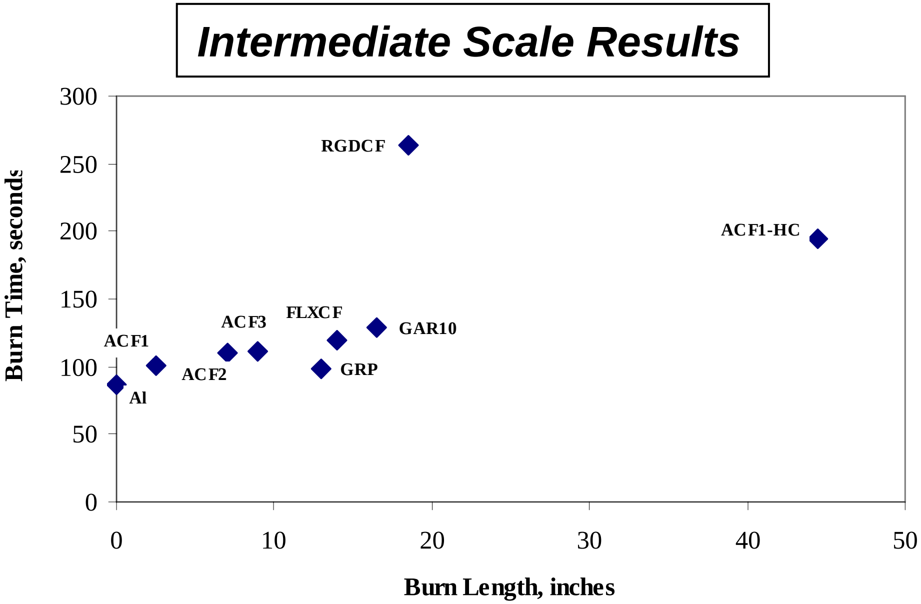
Radiant Panel Test Series #1

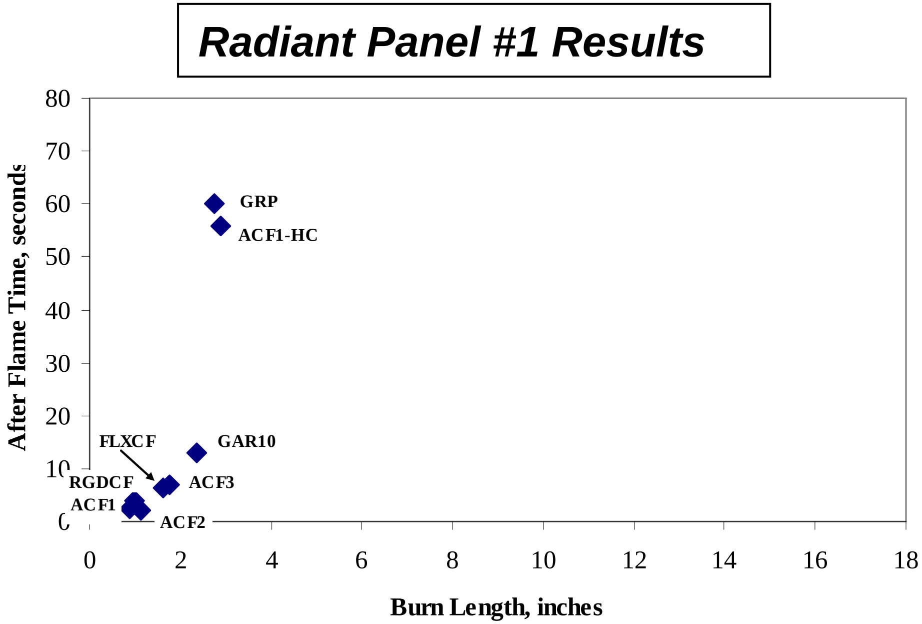
- **R&D Panel at FAATC Bldg 217**
- **Radiant heat panel set to 1.5 BTU/ft^{2}s at "zero position"**
- **Sample holder frame used to align samples with plane of "zero position"**
  - Sample size 11"W x 24"L
- **Test parameters**
  - 1 min pre-heat of sample
  - 15 sec. flame impingement

Radiant Panel Test Series #1 Results



Radiant Panel Test Series #1 Results





Radiant Panel Test Series #2

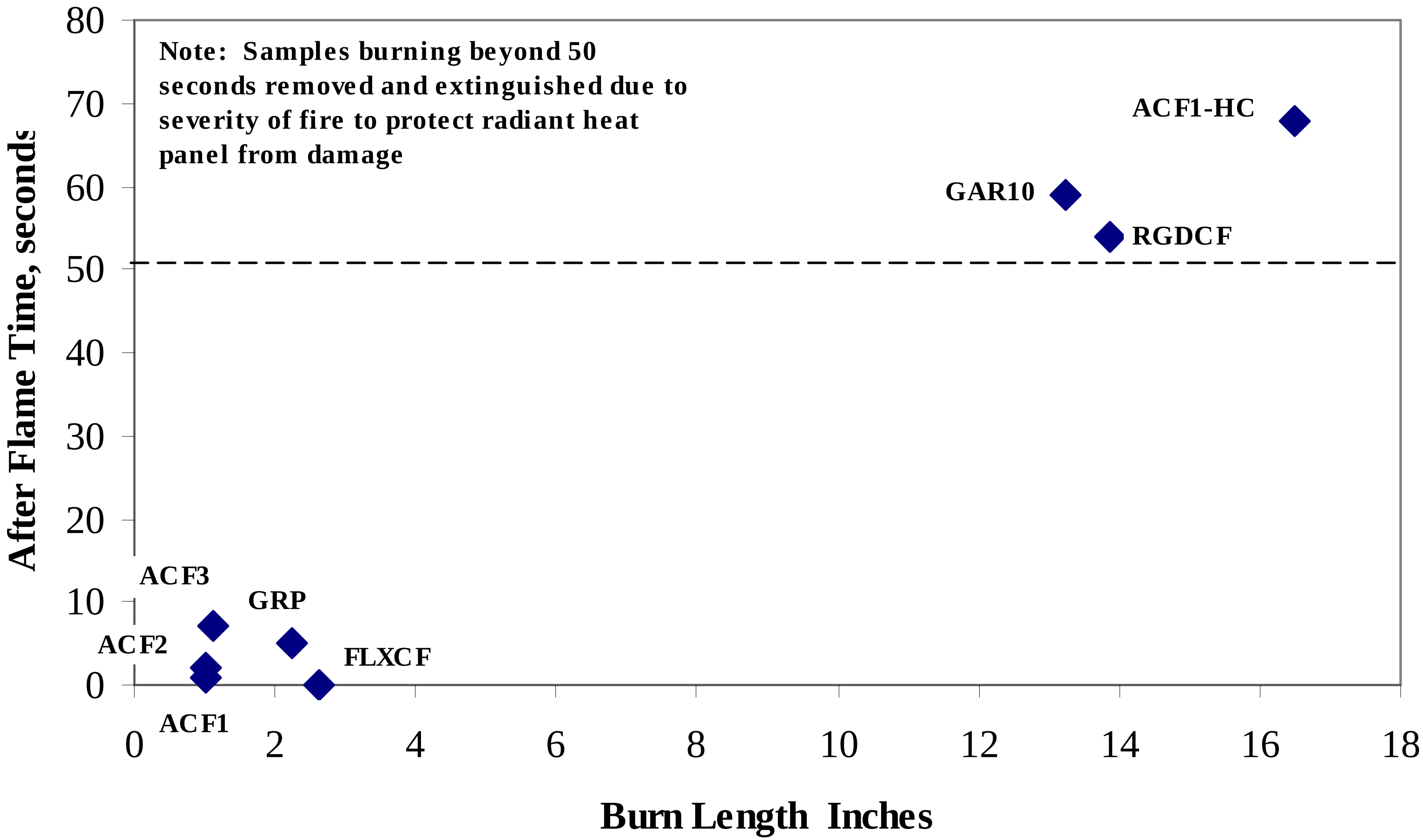
- **R&D Panel at FAATC Bldg 217**
- **Radiant heat panel set to 1.5 BTU/ft2s at "zero position"**
- **Sample holder frame used to align samples parallel to radiant panel**
  - 6 ¼" distance from panel
  - Sample intersects with "zero plane" at "zero position"
  - Sample size 11"W x 24"L
- **Test parameters**
  - 1 min pre-heat of sample
  - 15 sec. flame impingement

Configurations 1 vs 2, RGDCF

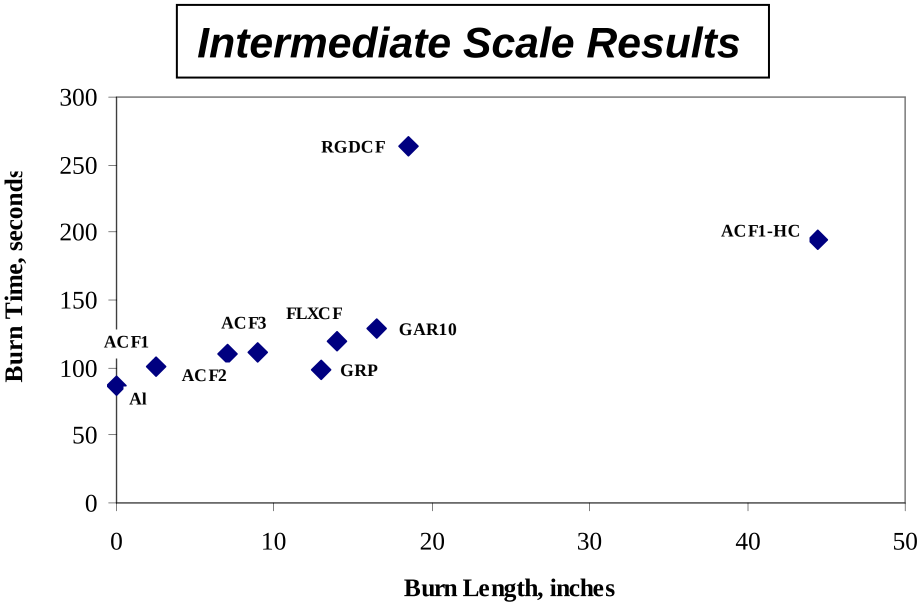
RGDCF Radiant Panel #1

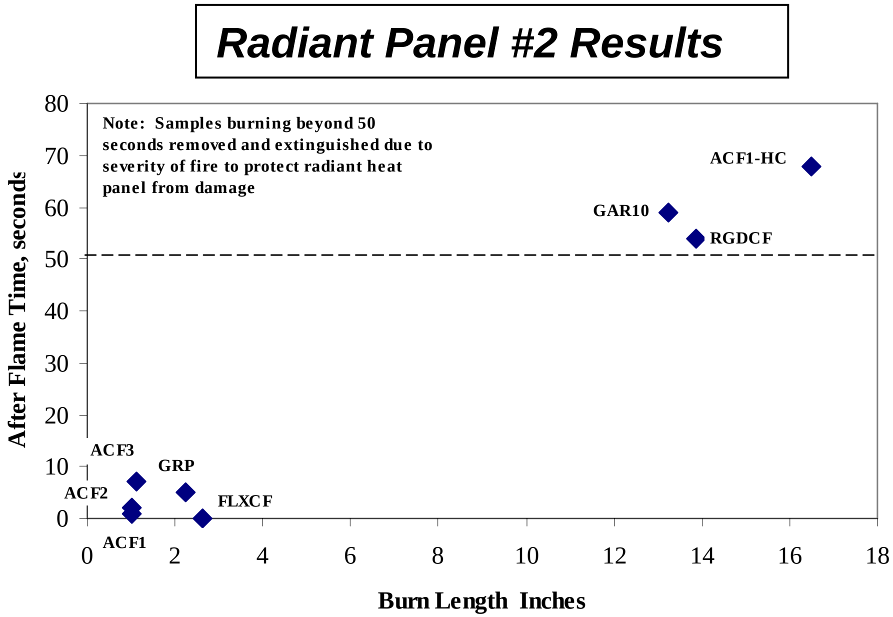
RGDCF Radiant Panel #2

Radiant Panel Test Series #2



Radiant Panel Test Series #2 Results





Summary

- An intermediate-scale test rig was developed and was successful in simulating the effects of a moderately severe hidden fire on the inboard side of a composite fuselage.

- A variety of composite materials, including aerospace grade and non-aerospace grade samples, were tested on the intermediate scale test rig and ranked according to their ability to propagate flames from the foam block hidden fire source.

- As expected, the solid laminate aerospace composite materials outperformed the non-aerospace composites. The aerospace composite sandwich panel, however, was the worst performer, due to the thin structural layers backed by an insulating honeycomb core.

Summary (cont.)

- **The test results emphasized the importance of qualifying the material and the sample configuration.**

- **The radiant panel apparatus, when calibrated to 1.5 BTU/ft2s with a one minute pre-heat, 15 second flame impingement, and sample orientation parallel to and six and one quarter inches from the radiant heat panel, was successful in replicating the fire worthiness ranking from the intermediate scale test.**

- **An appropriate pass-fail criteria would be a burn length not to exceed two inches and an after flame not to exceed ten seconds.**

Draft Technical Note

- **Submitted to FAA sponsor, management September 2010**
- **Submitted to FAA technical report editors with changes December 2010**
- **Will be posted on Fire Safety Website once complete**

ote technical note technic

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DRAFT

Robert I Ochs

December 2010

DOT/FAA/AR-TN

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This document is also available from the Federal Aviation Administration William J. Hughes Technical Center at actlibrary.tc.faa.gov.

U.S. Department of Transportation
Federal Aviation Administration

Radiant Panel #3 & #4

- **At the request of the task group, other configurations were explored in the radiant panel**

- **Increase heat flux to sample while making test configuration less complicated**
  – Lower radiant panel angle to 15° from horizontal
  – Lower sample angle to 10° from horizontal

R.P. moved to 15°

R.P. at 30°, Sample at 10°

R.P. Testing Summary

- **Adjusting RP angle to 15° from horizontal increases overall heat flux to sample**
  - Flame propagation occurs in the wrong direction, towards sample edge
- **RP angle returned to 30° from horizontal and inclining sample plane to 10° from horizontal (to clear drawer height)**
  - No flame propagation and minimal after flame time
- **So far, only RP configuration that correlates to intermediate scale testing is 30° panel and 30° sample (parallel configuration)**

Questions?

Contact:
Robert I. Ochs
DOT/FAA Technical Center
Building 287
Aircraft Components Fire Test Facility
Atlantic City Int'l Airport, NJ 08405
phone: (609) 485-4651
fax: (609) 646-5229
robert.ochs@faa.gov
http://www.fire.tc.faa.gov

30° RP Tester Configuration

Axis of burner is aligned with pivot axis of sample holder.

Two screws are used as stoppers to prevent the sample holder from sliding forward when it tilts up

Note bottom of sample holder is cut out to allow sample to slide down when inclined

Composite Flame Propagation Test Method Development

Intermediate Scale Test Rig Dimensions

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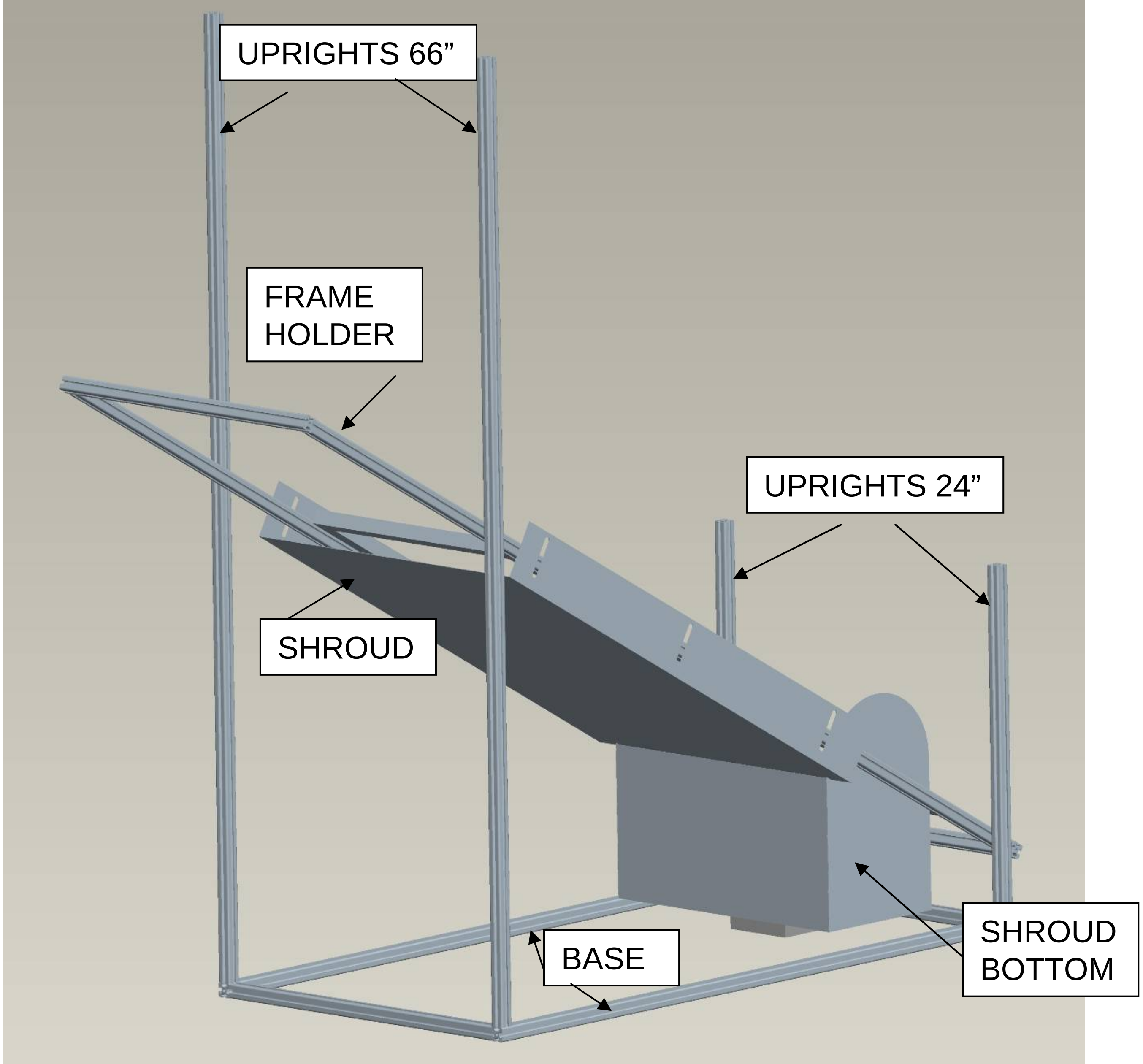
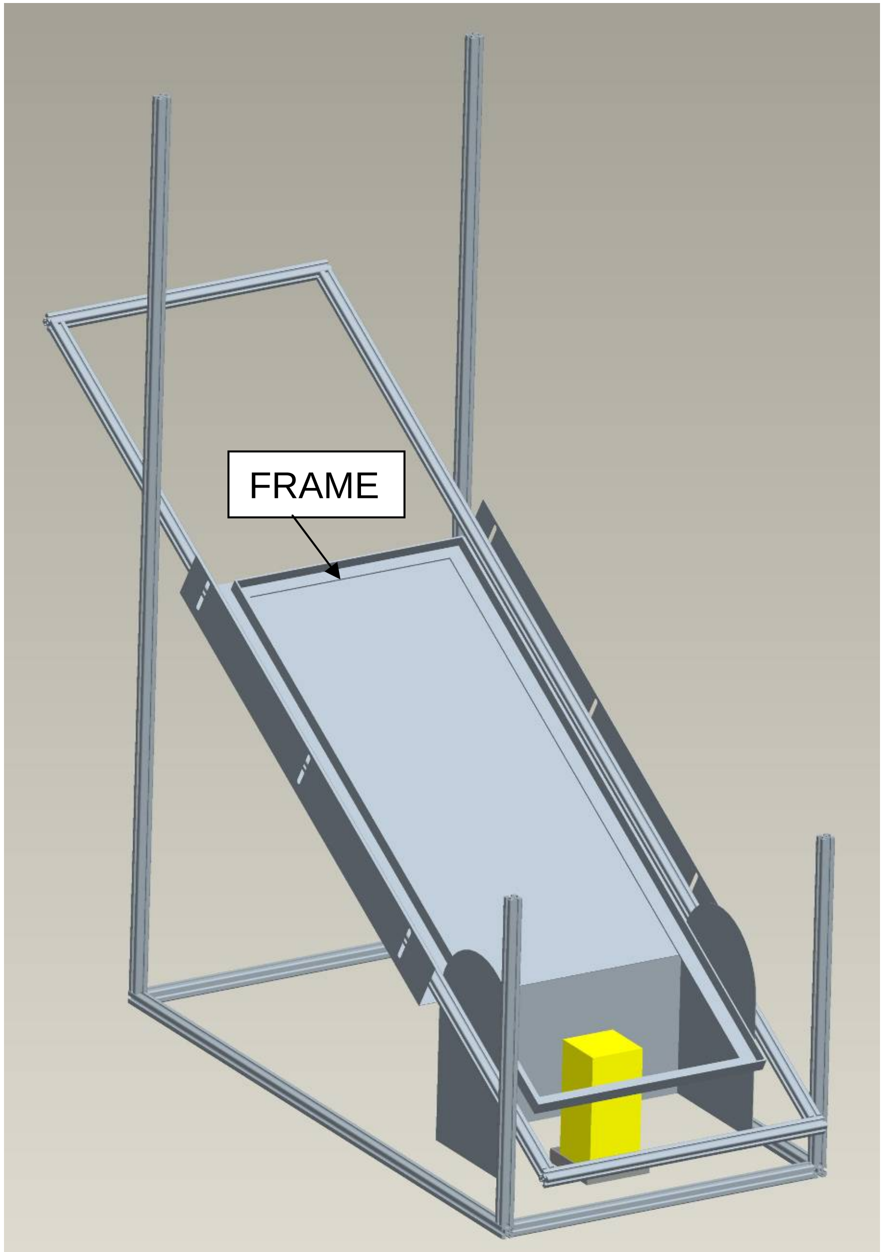

UPRIGHTS 66”
FRAME
HOLDER
UPRIGHTS 24”
SHROUD
BASE
SHROUD
BOTTOM


FRAME

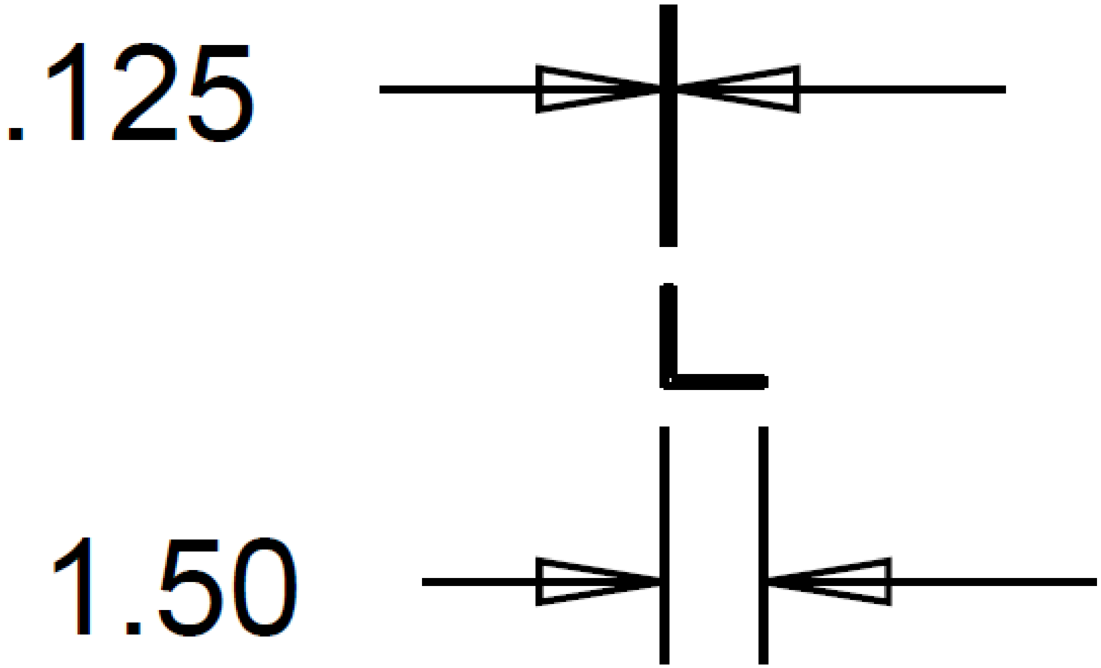
Materials

- Base, Uprights, Frame Holder are constructed from inch solid extruded aluminum t-slotted framing, McMaster Carr p/n 47065T101
- Frame constructed from 1.5”, .125” thick steel angle
- Shroud and Shroud Bottom constructed from .040” thickness galvanized sheetmetal

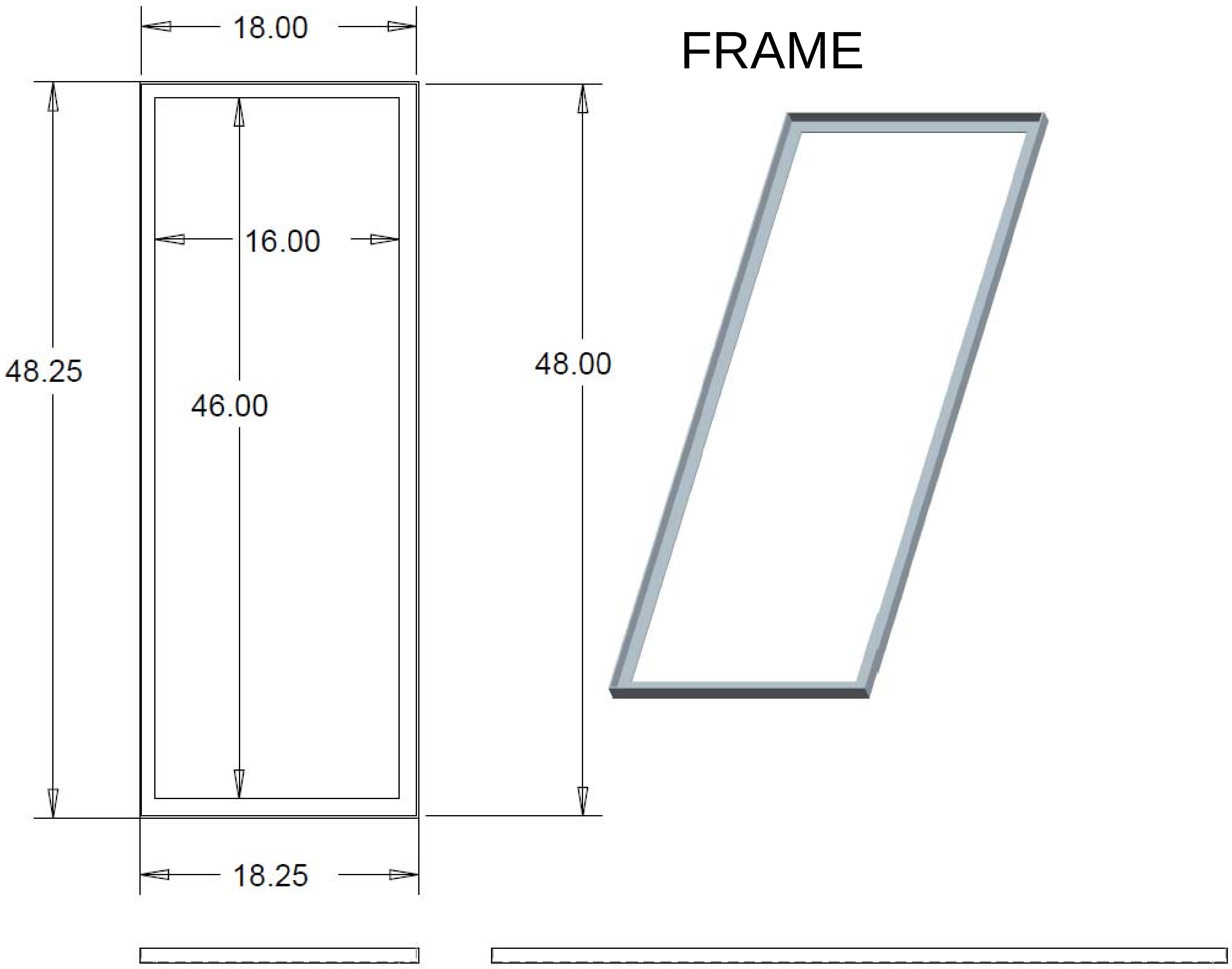
Assembly Notes

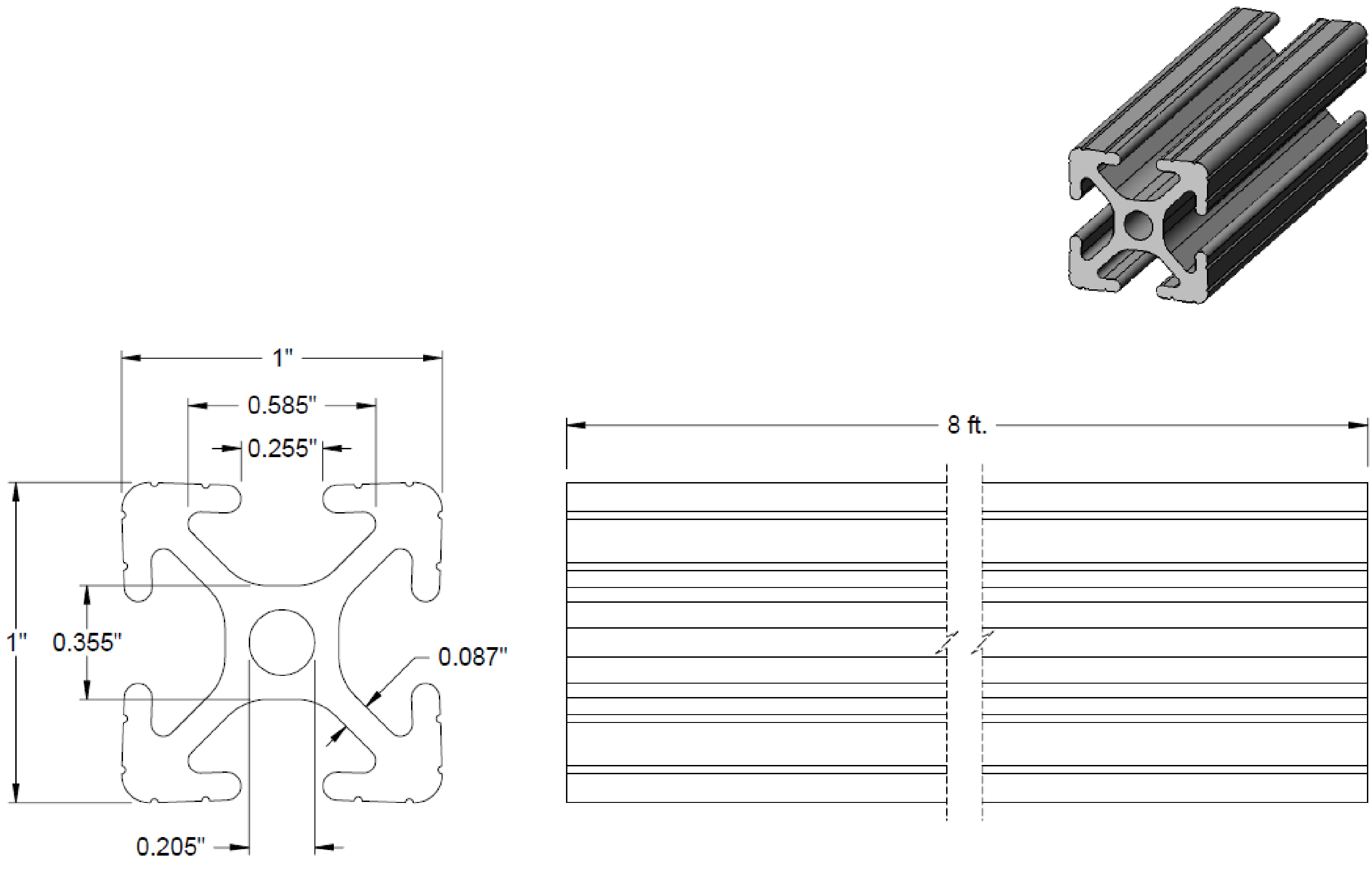
- Extruded aluminum t-slotted framing from McMaster Carr was used to construct rig
- Use components like angle brackets, sliding guide blocks to connect components
- http://www.mcmaster.com/#t-slot-rails/=by2fcz
- Search www.mcmaster.com for "t-slot" to get all components

•1.5” steel angle, .125” thickness



FRAME





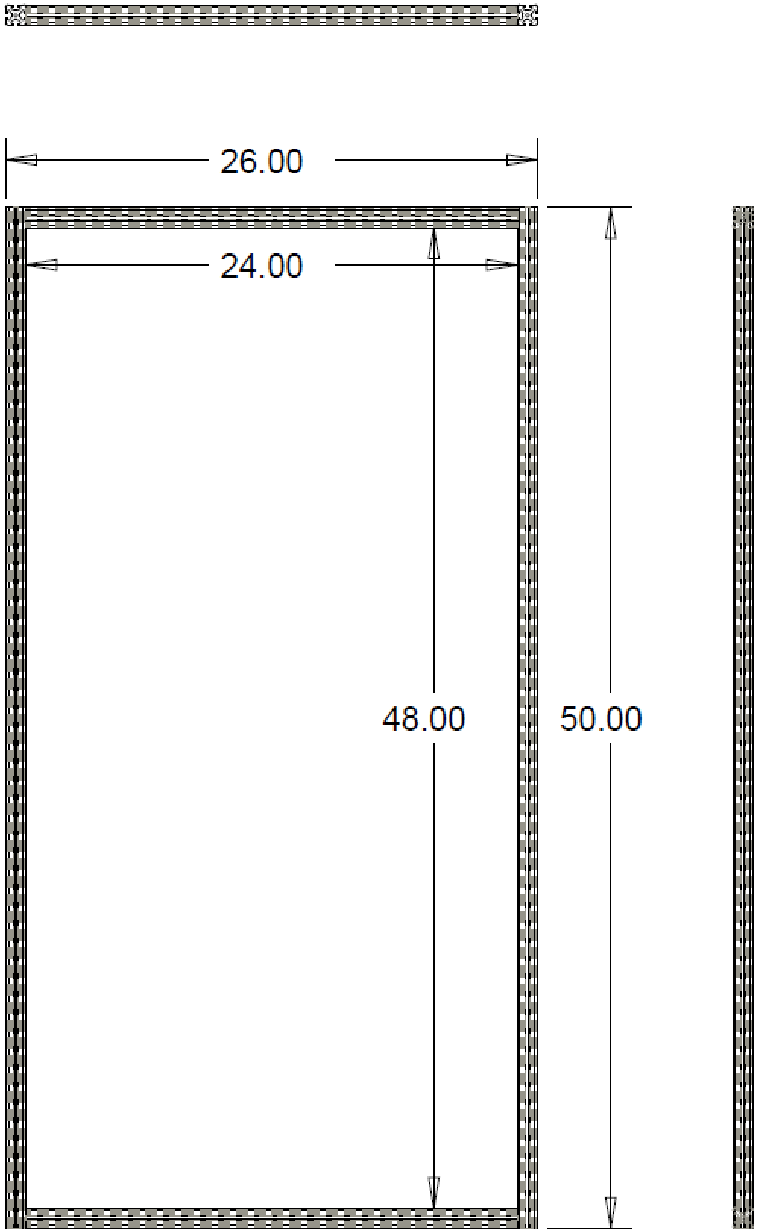
McMASTER-CARR® CAD

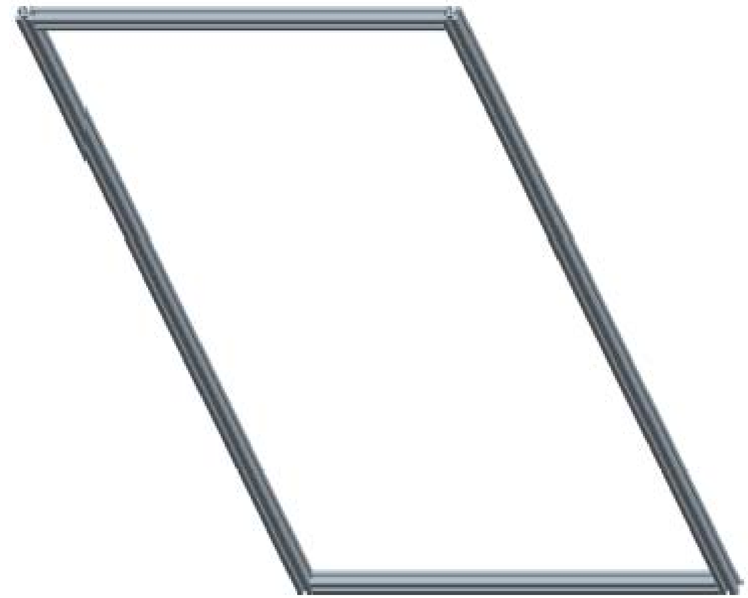
PART NUMBER 47065T123

http://www.mcmaster.com

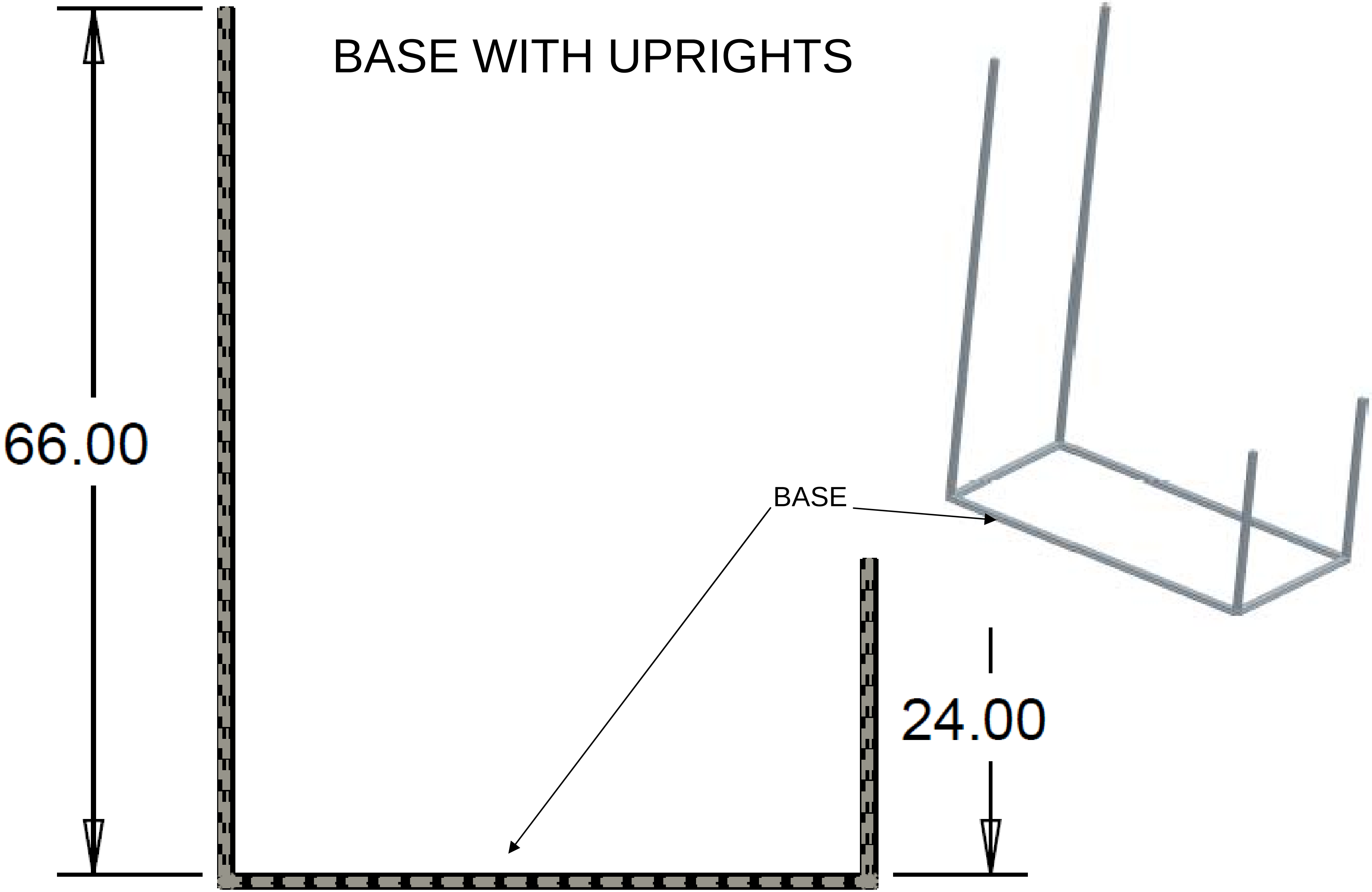
Aluminum Four-Slot Single Extrusion

BASE

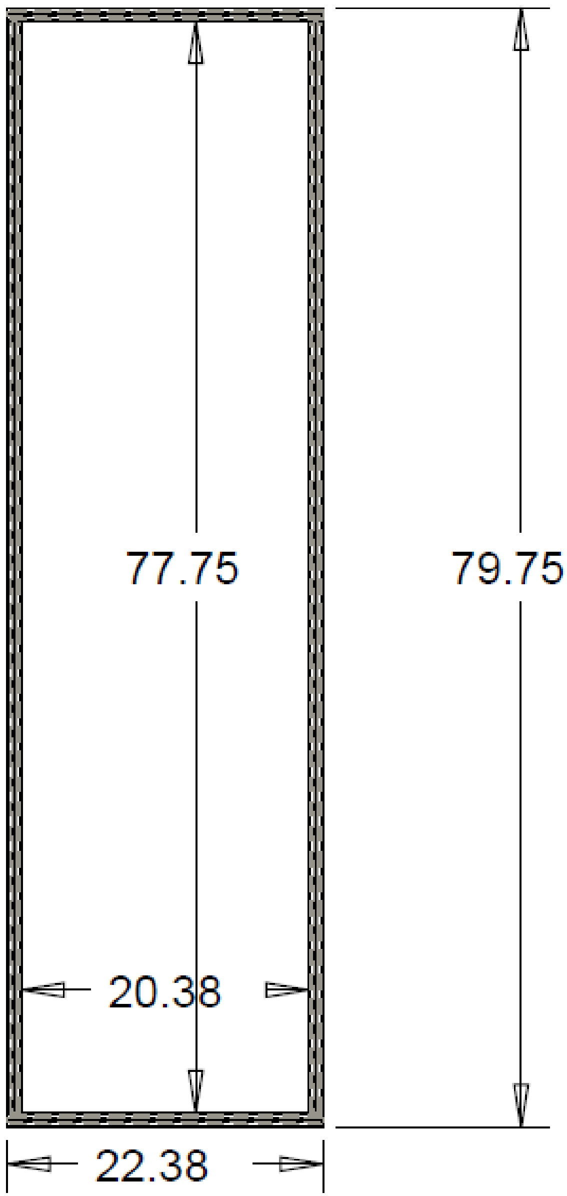


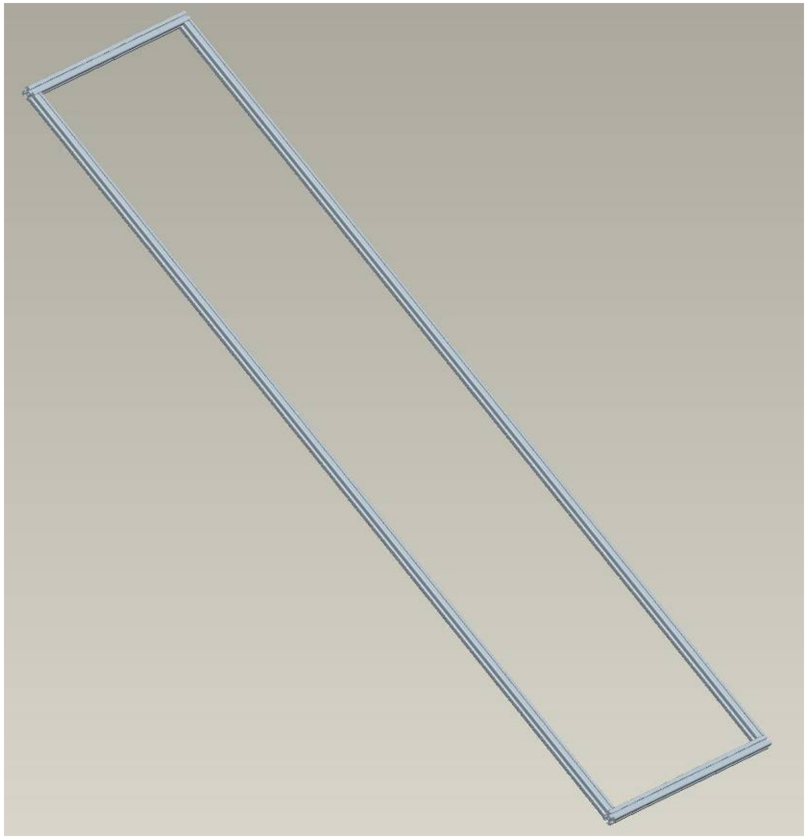


BASE WITH UPRIGHTS

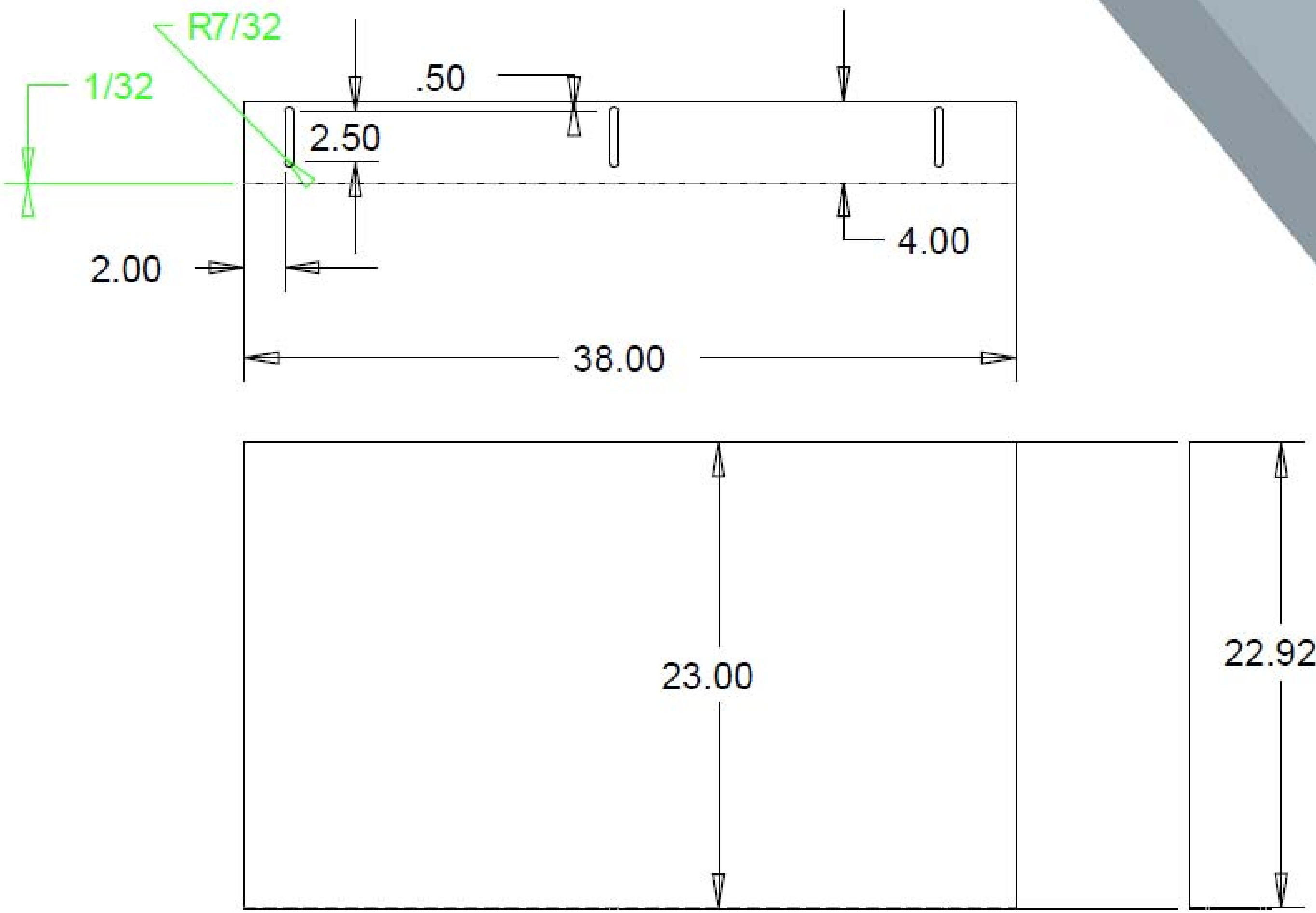


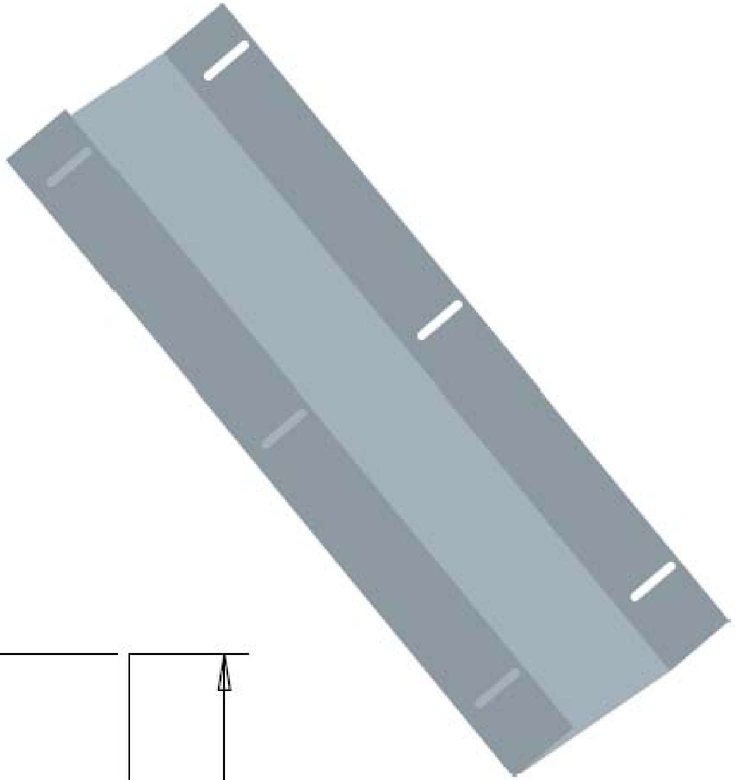
FRAME HOLDER





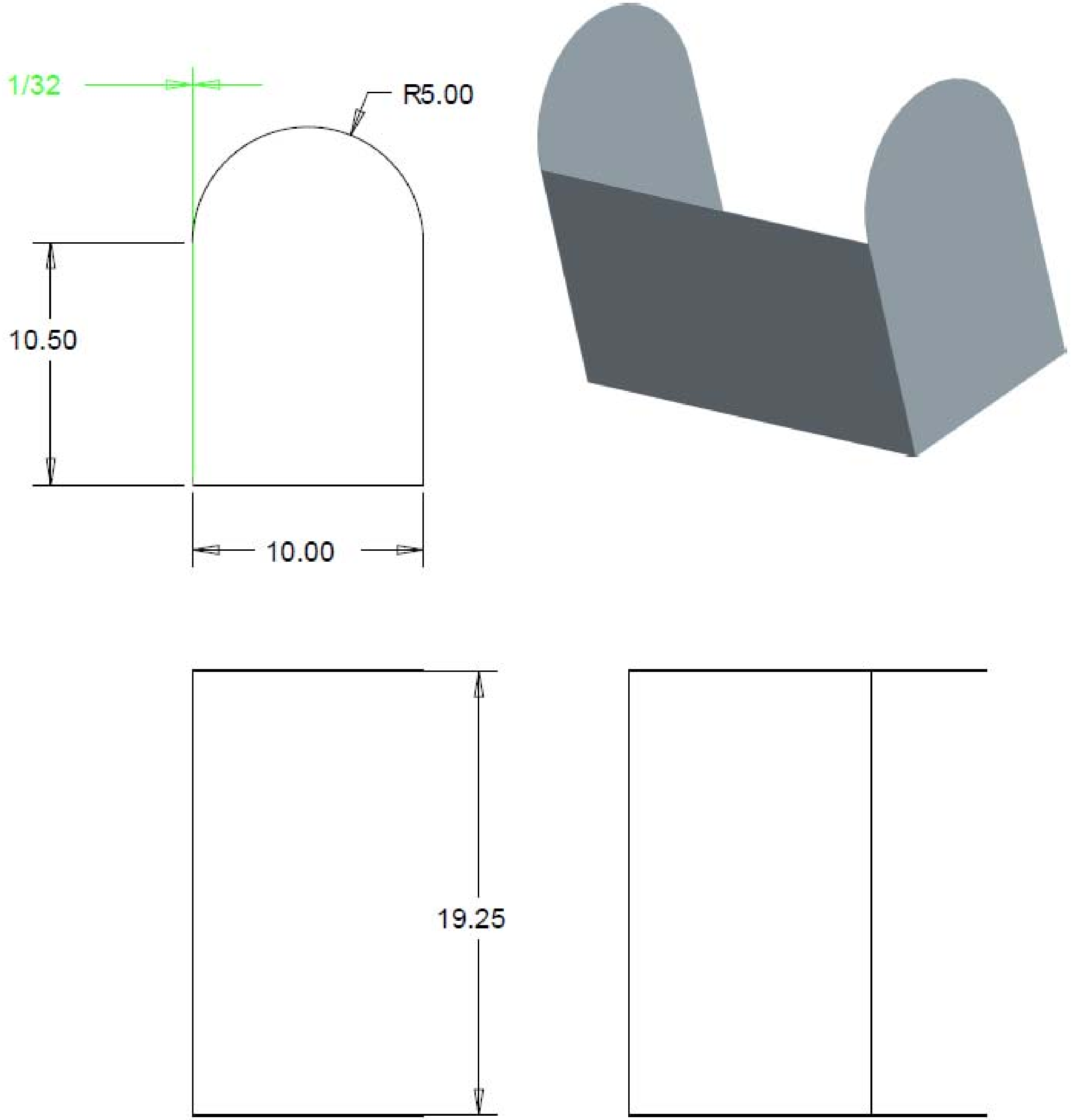
SHROUD





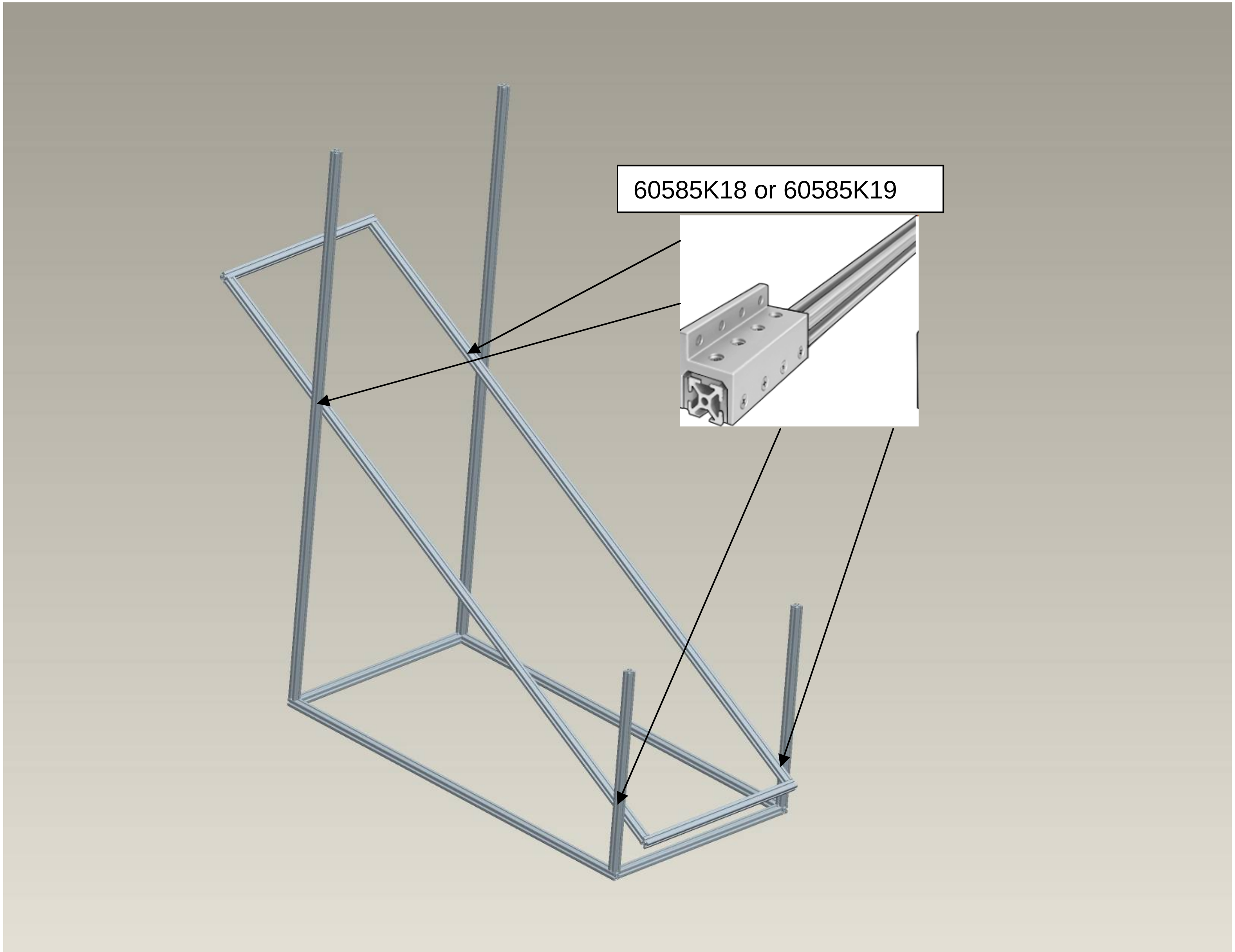
SHROUD

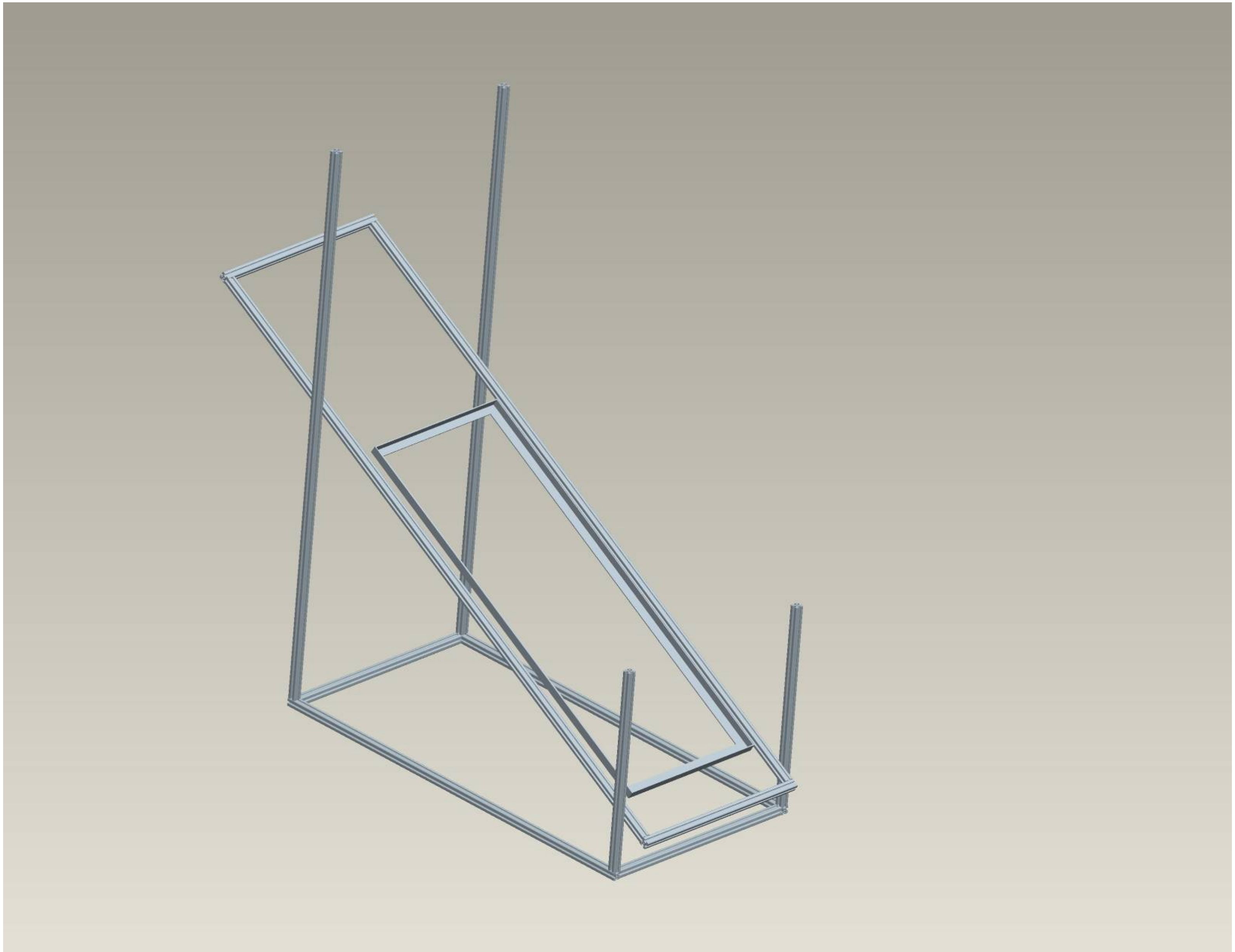
BOTTOM

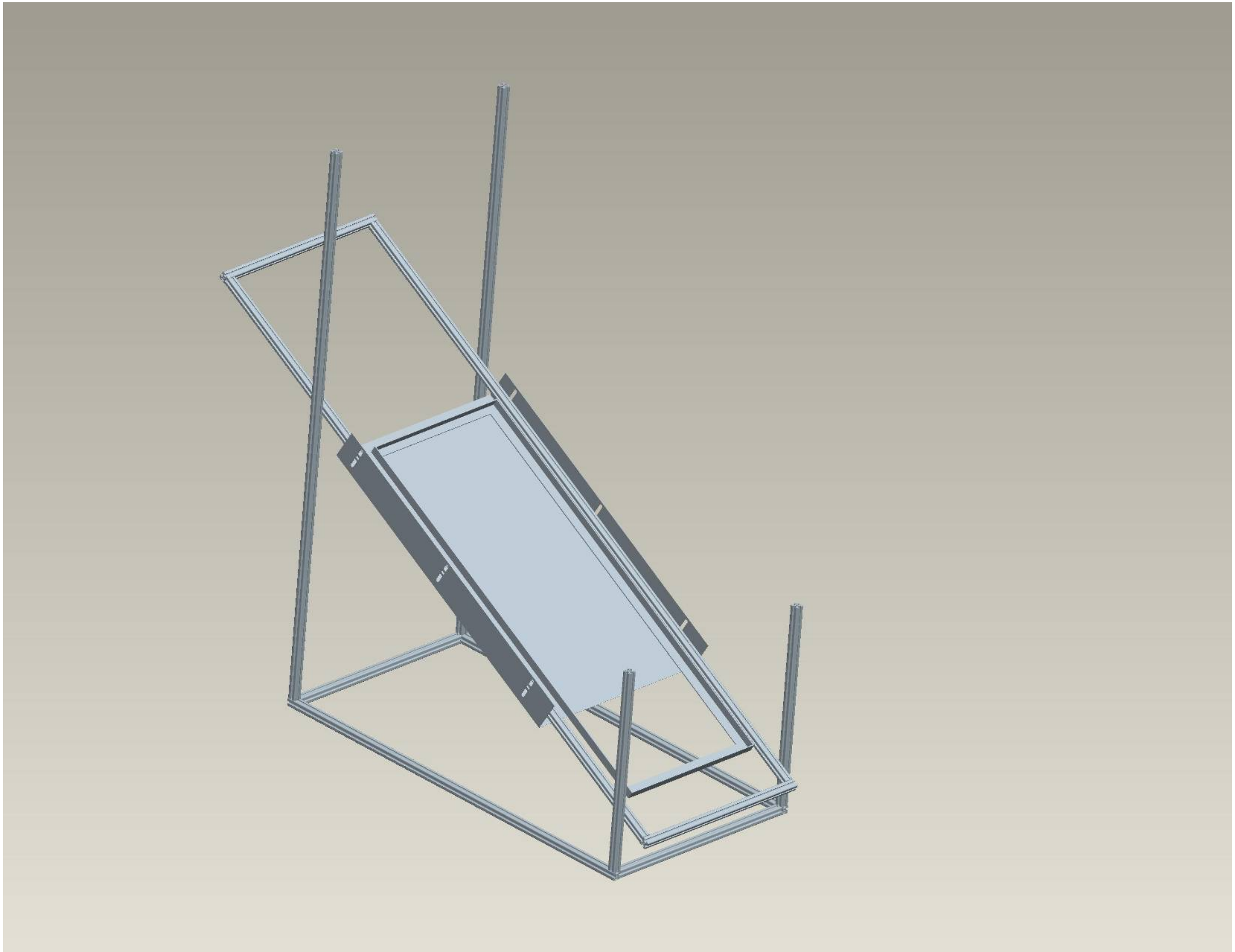


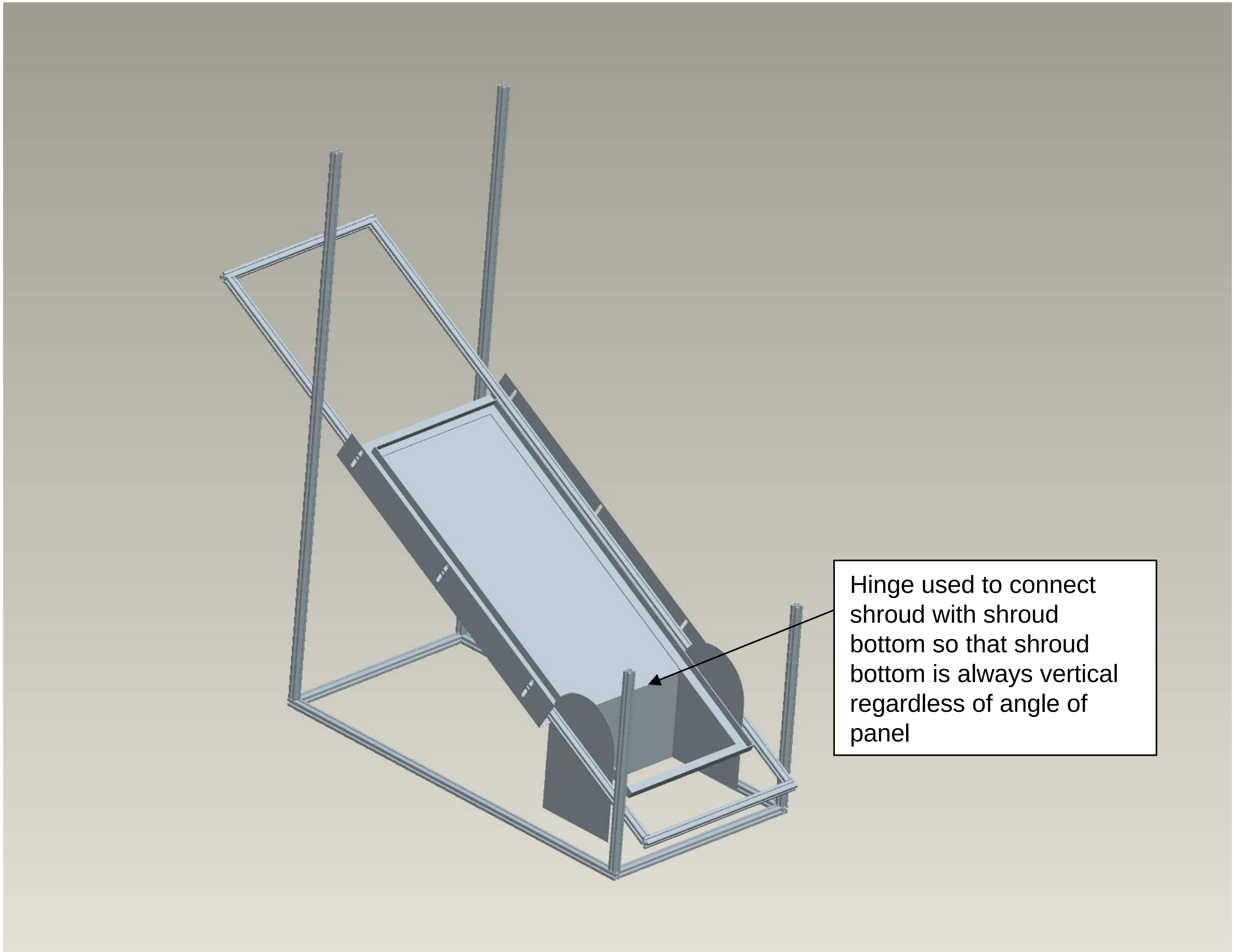
Note:

- **Both "shroud" and "shroud bottom" are lined on all interior sides with ½" thick Kaowool ceramic fiberboard**


60585K18 or 60585K19






Hinge used to connect shroud with shroud bottom so that shroud bottom is always vertical regardless of angle of panel