2022 SAE Government Industry Meeting

NHTSA

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Status of NHTSA's Roof Ejection Mitigation Research

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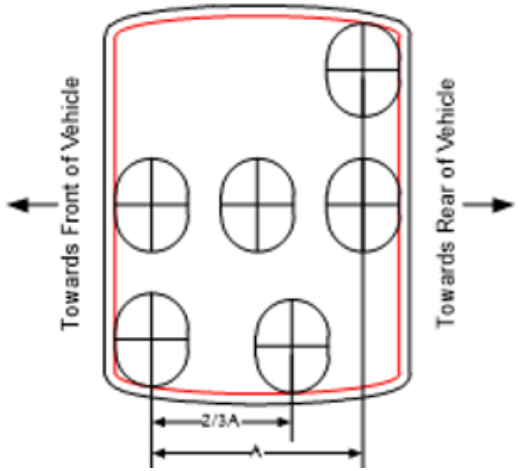
Background

- Annual average 87 fatalities (FARS 2004-2017, coded as roof ejection path)
  - "Occupant Injuries Related to Rollover Crashes and Ejections from Recent Crash Data" Jingshu Wu et. al. 26th ESV, 2019
- Tests on production vehicles with laminated sunroof panels at 16, 20 km/h
  - 2009 Ford Flex (fixed); 2014 Ford CMax (fixed); 2013 Subaru Forester (movable)
    - 2016 SAE Government Industry Meeting
    - Paper at 25th Conference on Enhanced Safety of Vehicles (ESV), Detroit, 2017
- Tests on production and countermeasure* sunroof panels at 14, 16, 20 km/h
  - 2016 Ford F-150* (laminated - inner slider); 2010 Toyota Prius (fixed polycarbonate); 2019 Aisin (laminated - outer slider)
    - Paper at 26th Conference on Enhanced Safety of Vehicles (ESV), Eindhoven, Netherlands, 2019
  - Lincoln MKZ (Protec II – outer slider)
    - Presented at 2020 SAE Government Industry Meeting
- Tests done on roof air curtains at 14, 16 and 20 kph, 6 locations
  - Hyundai-Mobis Roof Air Curtain (prototype curtain)
    - Presented at 2020 SAE Government Industry Meeting

Test Setup

- FMVSS No. 226 Impactor
- Featureless headform (40 lbs. [18kg])
- Displacement, speed from Linear Pot (LVDT)
- Accelerometer on the ram

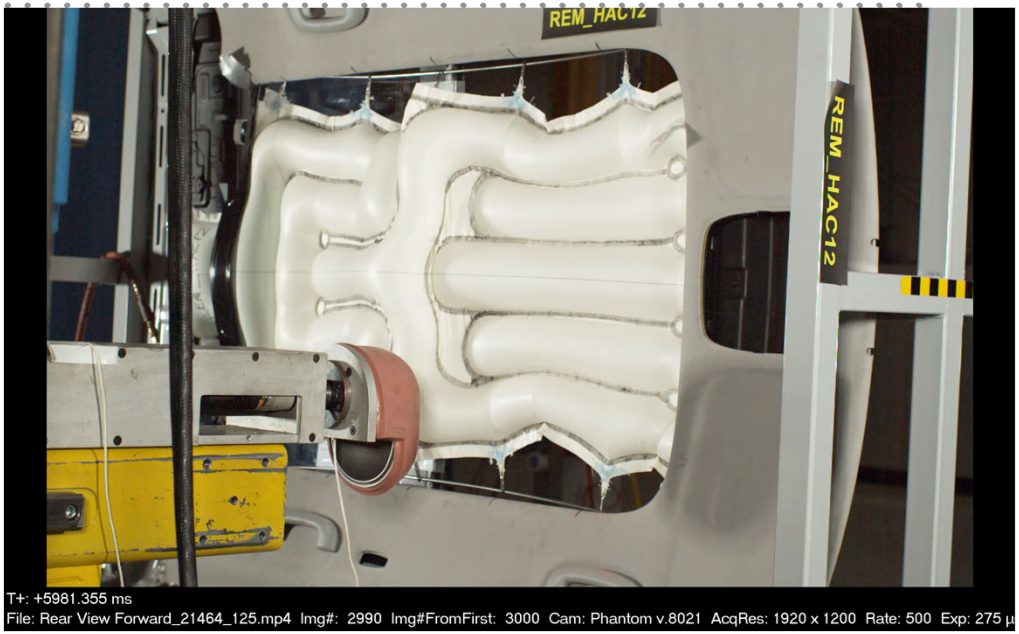
Linear Variable Differential Transformer (LVDT)

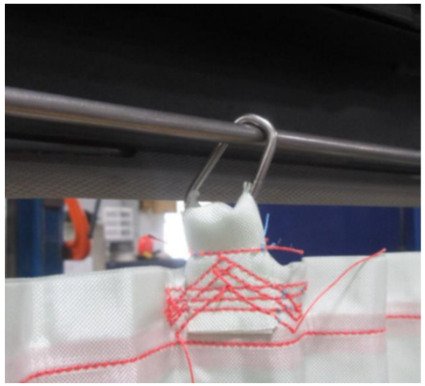


- Impact locations and speeds
  - Speeds (14/16/20 km/h)
  - Assumes
    - Left-right side are identical
    - Front-back are NOT identical
  - Test each panel at
    - Front corner
    - Rear corner
    - Center
    - Mid-point of front transverse edge
    - Mid-point of rear transverse edge
    - At 2/3 of longitudinal edge

Summary of Hyundai Testing

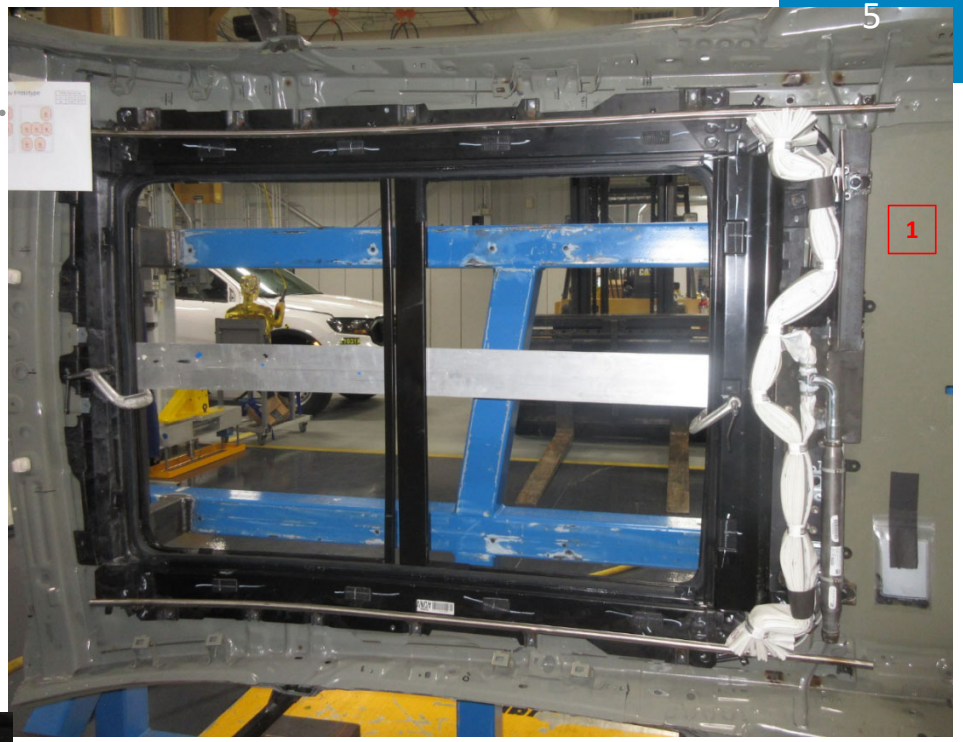
- Prototype air curtain by Hyundai-Mobis
- Module with headliner and plexiglass on rear panel
- Bag deployed rear to front, however, had deployment issues so was hand opened for all tests
- Deployed along guide rods mounted on lateral edges, guide rings sewn to bag
- Failure modes included full and partial ripping of the bag from the ring at stitching





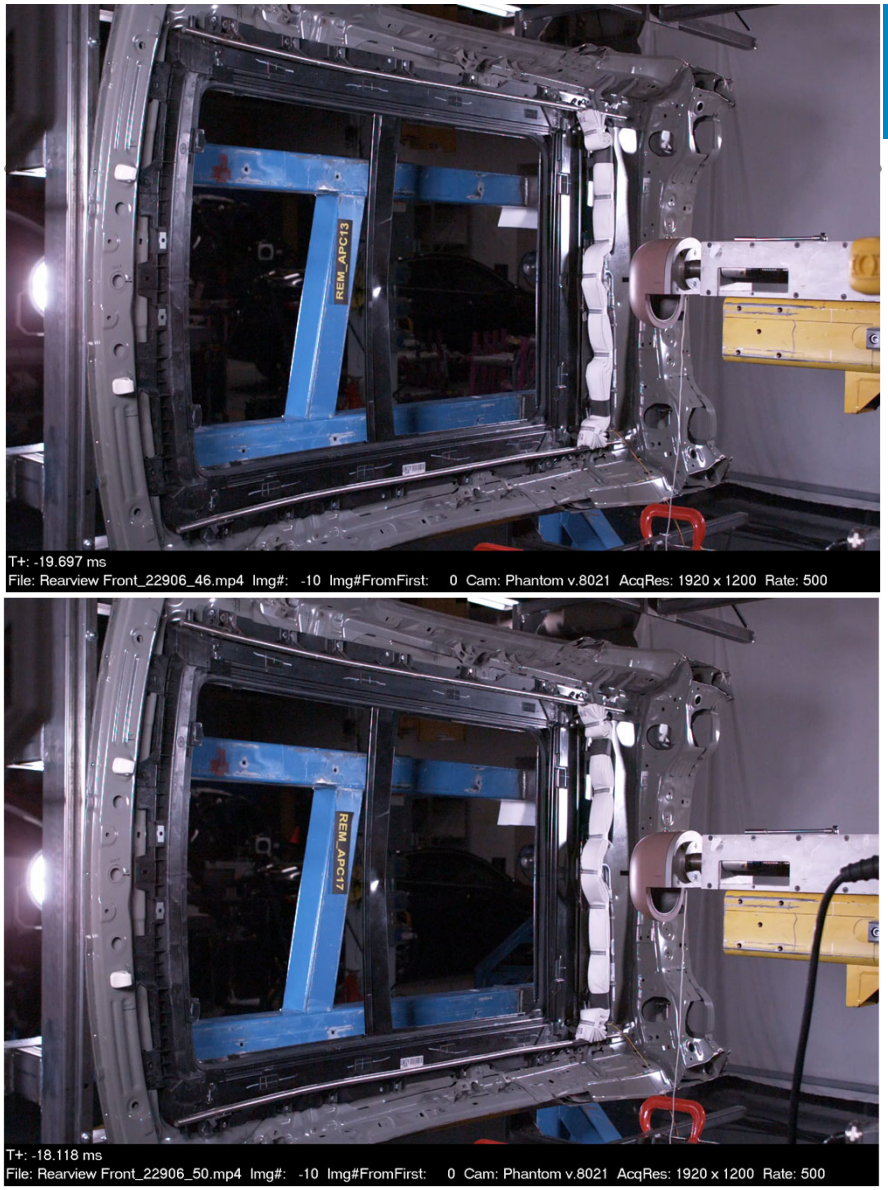
Autoliv Air Curtains

- Small crossover SUV frame, no headliner
- Air bag module mounted at rear of opening
- Bullet in rail deployment system
  - Five attachment points per side, sewn to curtain
  - Rails are stainless steel tubing mounted onto frame
- Latches at ends of rails to catch

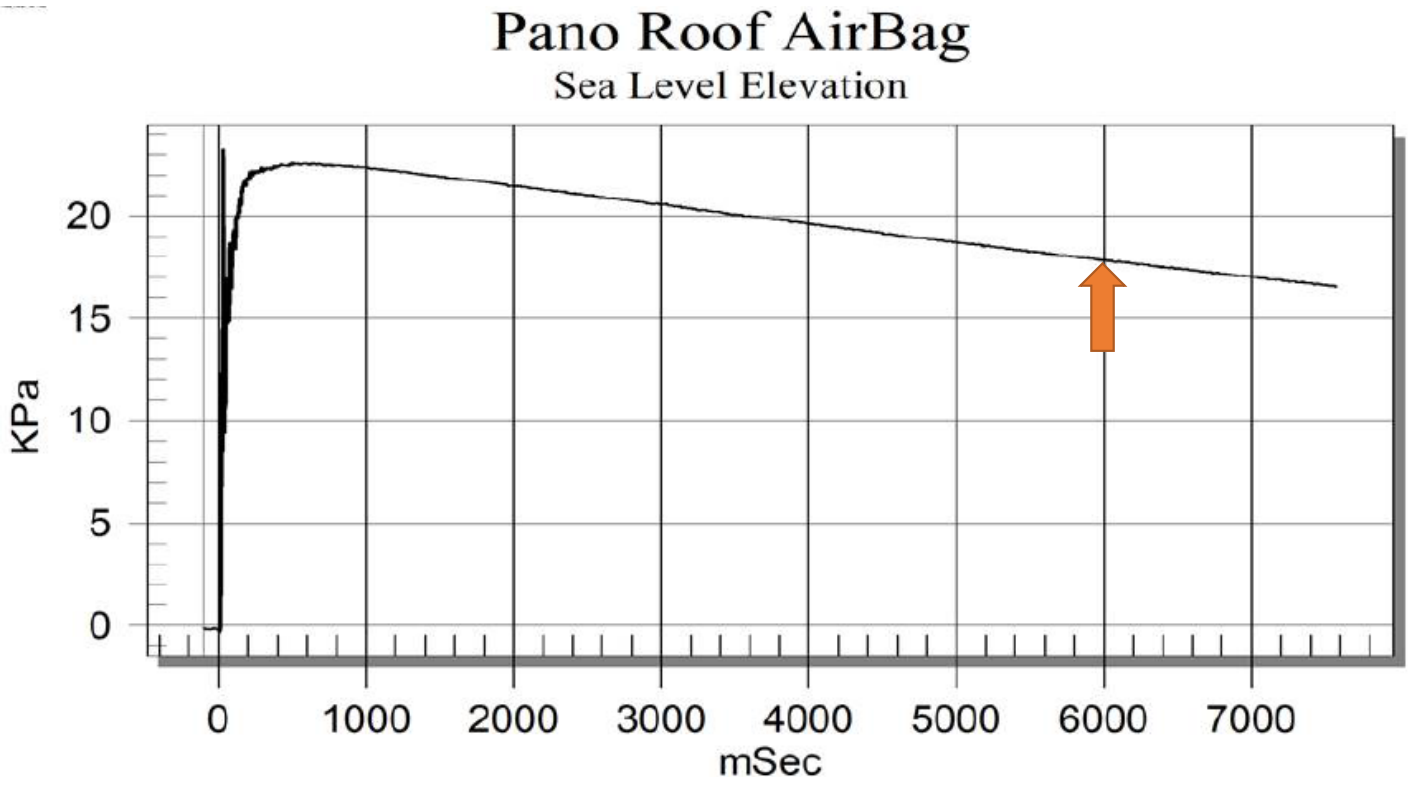


Autoliv Air Curtains

- One Piece Woven material
- T-joint gas guide inflator with chambers as shown in video
  - 4 mol inflator
- Deployable roof air curtain
  - 14 full deployments, 14 hand opening tests
  - Deployments that failed were getting caught on middle support member



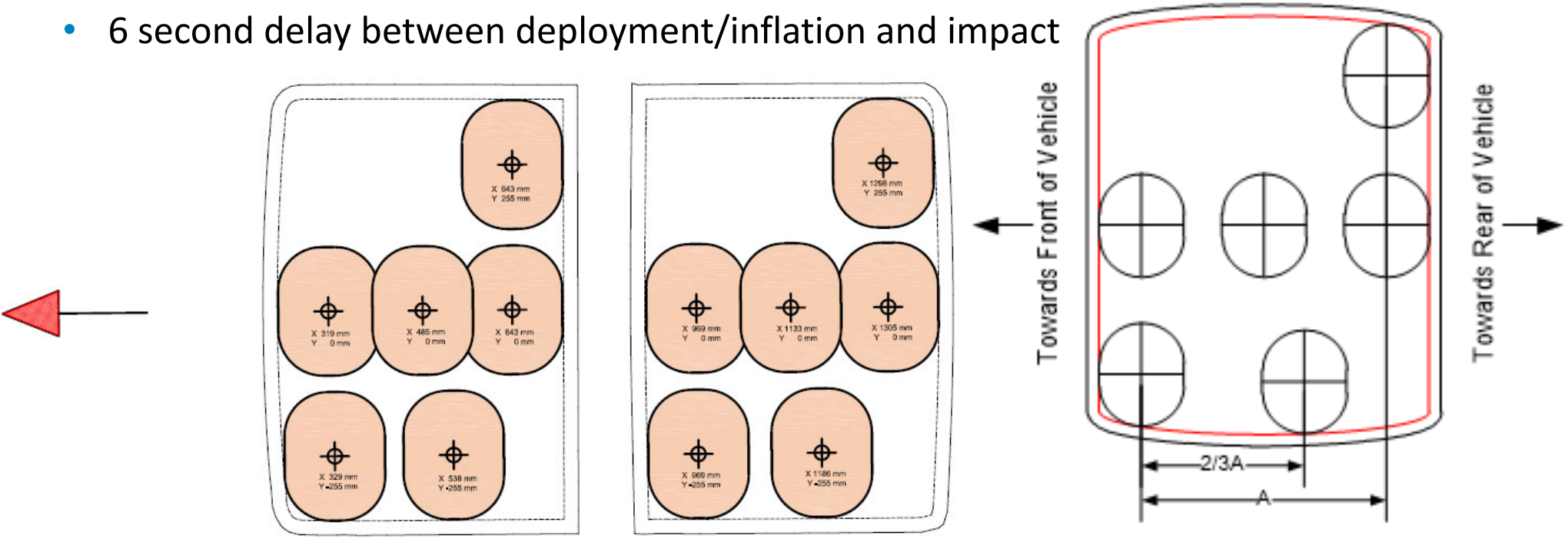
Air Bag Time Profile



- Deployment of bag across opening took approximately 50ms
- It is not expected that hand opening would influence pressure in bag during impact
- Impact occurs at 6000 ms after transients have settled down (orange arrow)

Test Setup

- Impact locations shown in figure below
- Impacts at 14, 16 and 20 kph (at first contact with the deployed curtain)
- Mix of full deployments and hand opening bag before firing inflator
  - 14 full deployments, 14 hand opening tests
- 6 second delay between deployment/inflation and impact

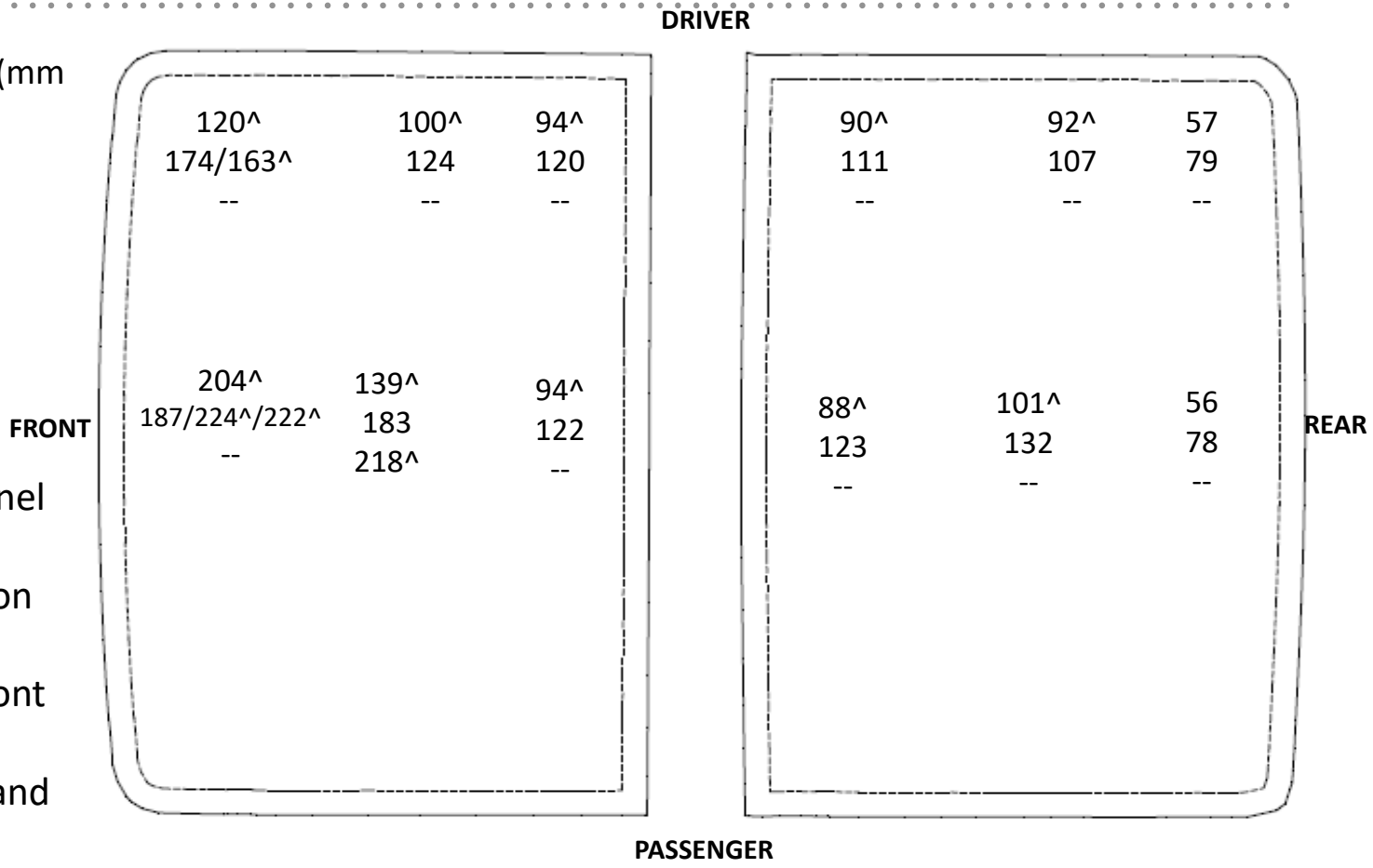


Excursion Results

Excursions from closed glass panel (mm

At 14 kph
At 16 kph
At 20 kph

^ = bag pre-opened

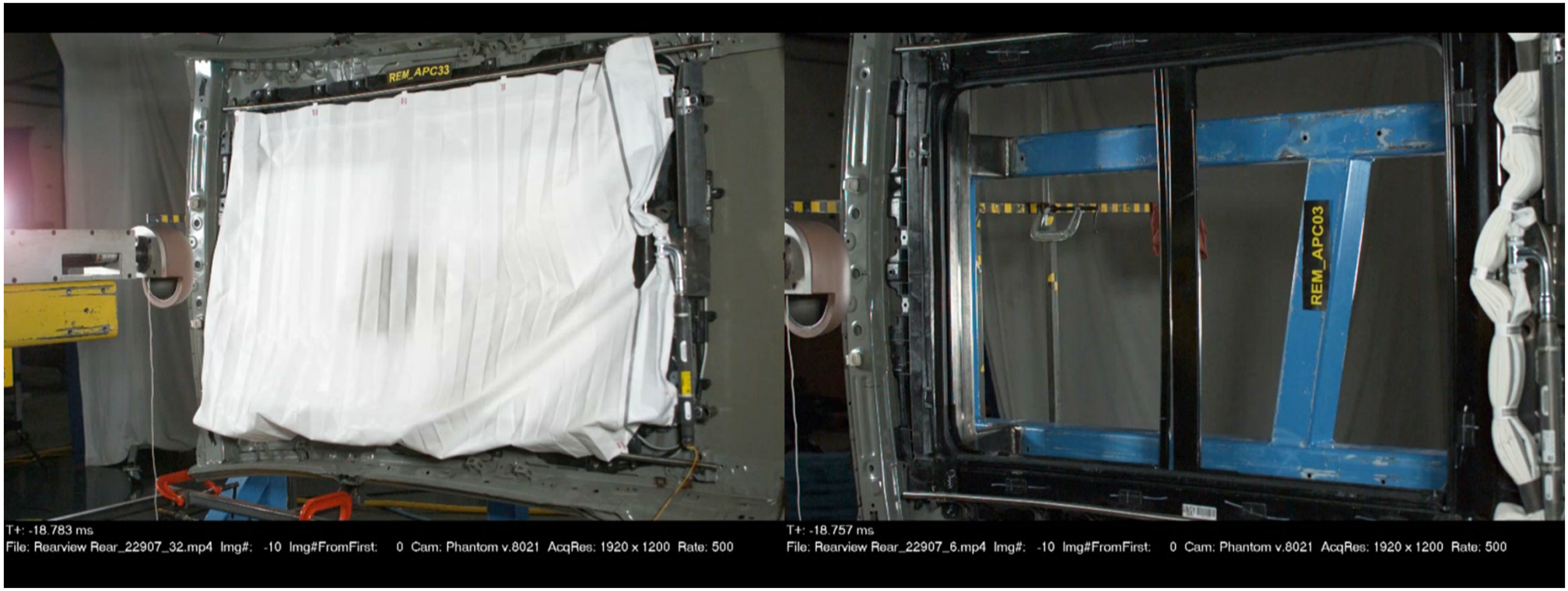


- Greater excursions on front panel than rear panel
- Excursions less in corners and on lateral edges
- Repeatability at front panel, front edge
  - Repeatable result when hand opened
  - Slightly different result from deployed (37mm)

Self-Deployed vs. Hand Opened

Hand-opened (224 mm)

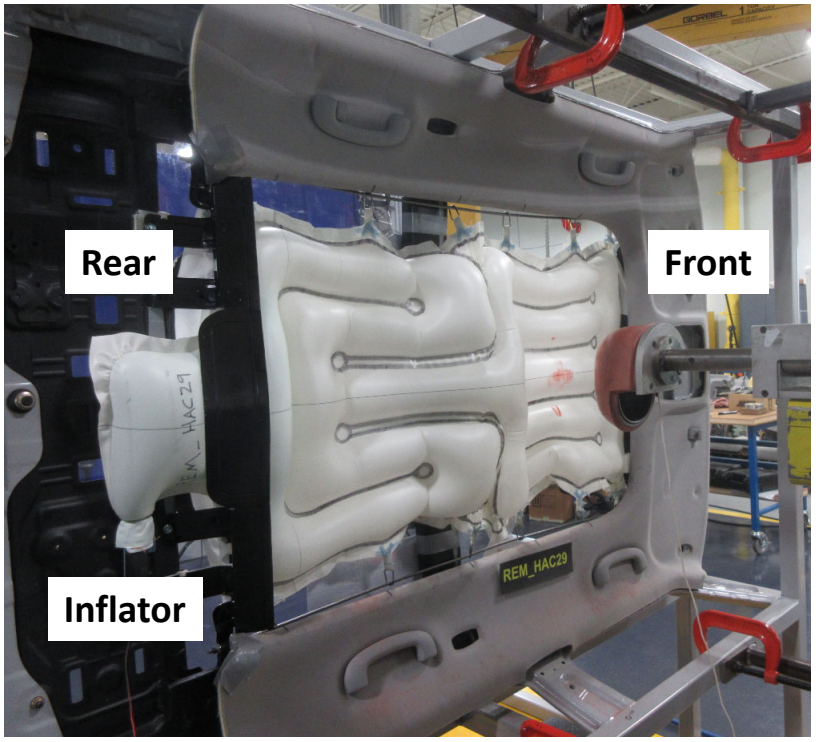
Deployed (187 mm)



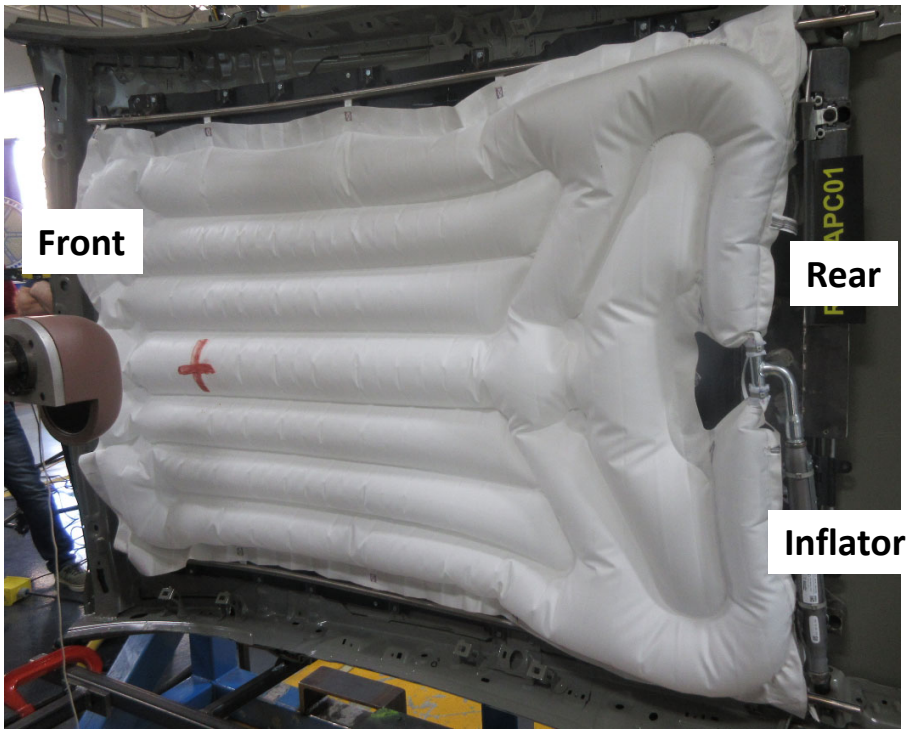
Front Panel Front Edge – 16kph

Comparison with Hyundai-Mobis Design

Hyundai-Mobis



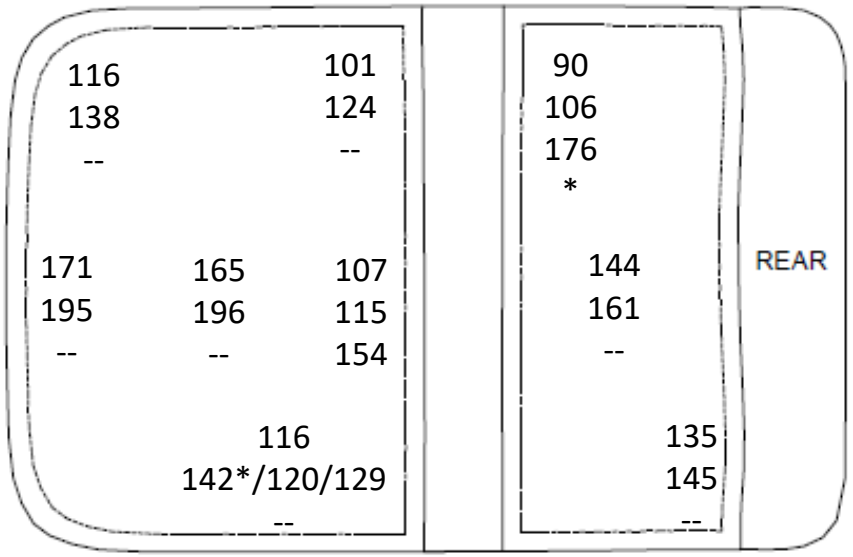
Autoliv



- Both bag designs contained headform when bag deployed correctly
  - Hyundai bag smaller and did not cover full opening, Autoliv bag larger and covered full opening
- Both designs in development but show feasibility for use with the current procedure
- Excursion limits may need adjustment for deployable curtains with open portals

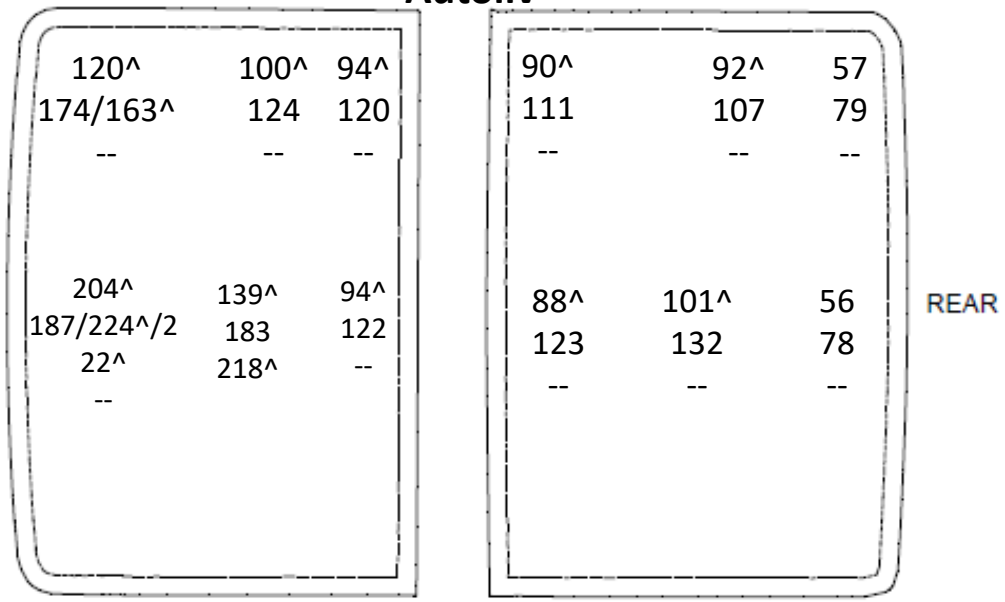
Comparison with Hyundai-Mobis Results

Hyundai-Mobis



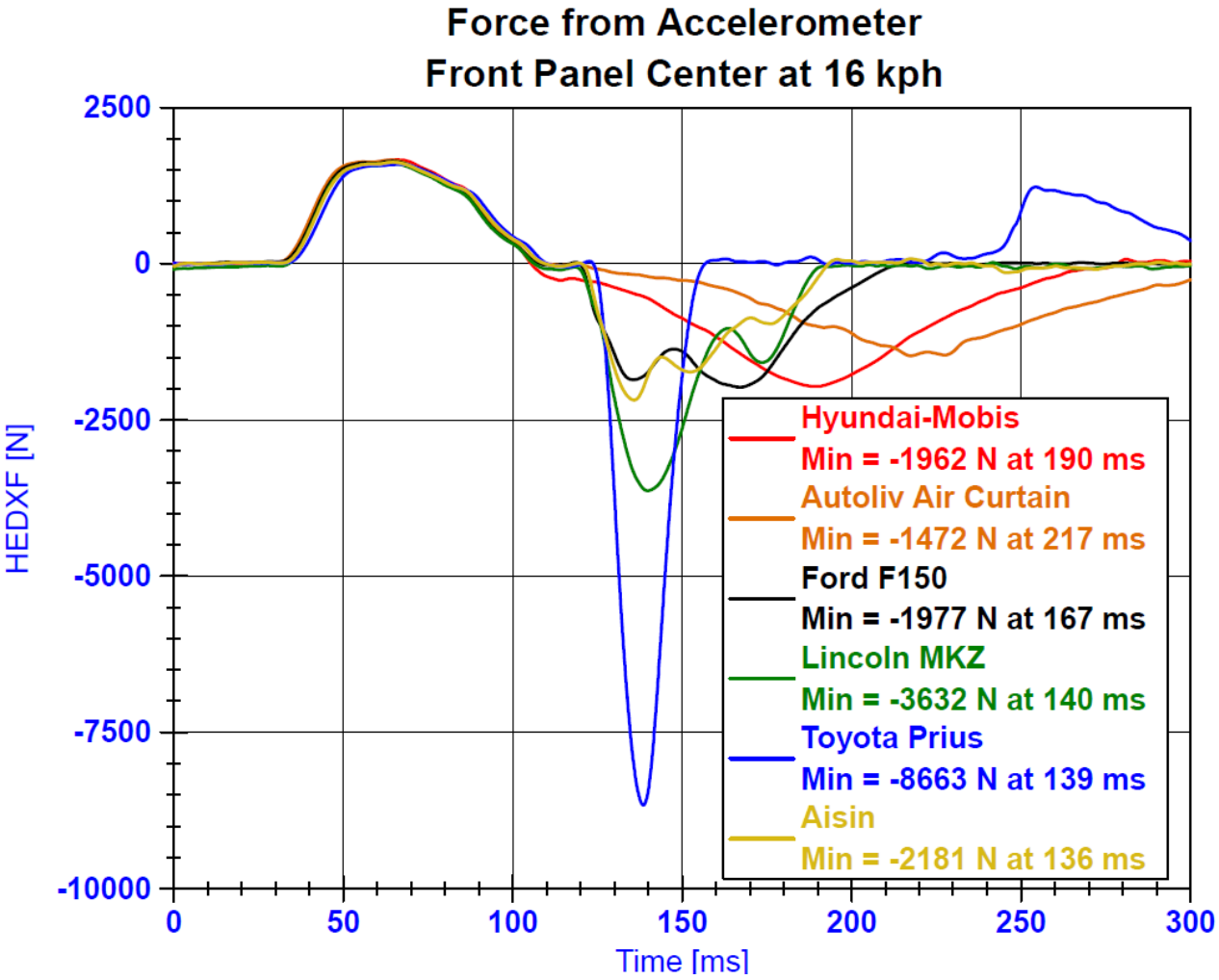
14 kph
16 kph
20 kph

Autoliv



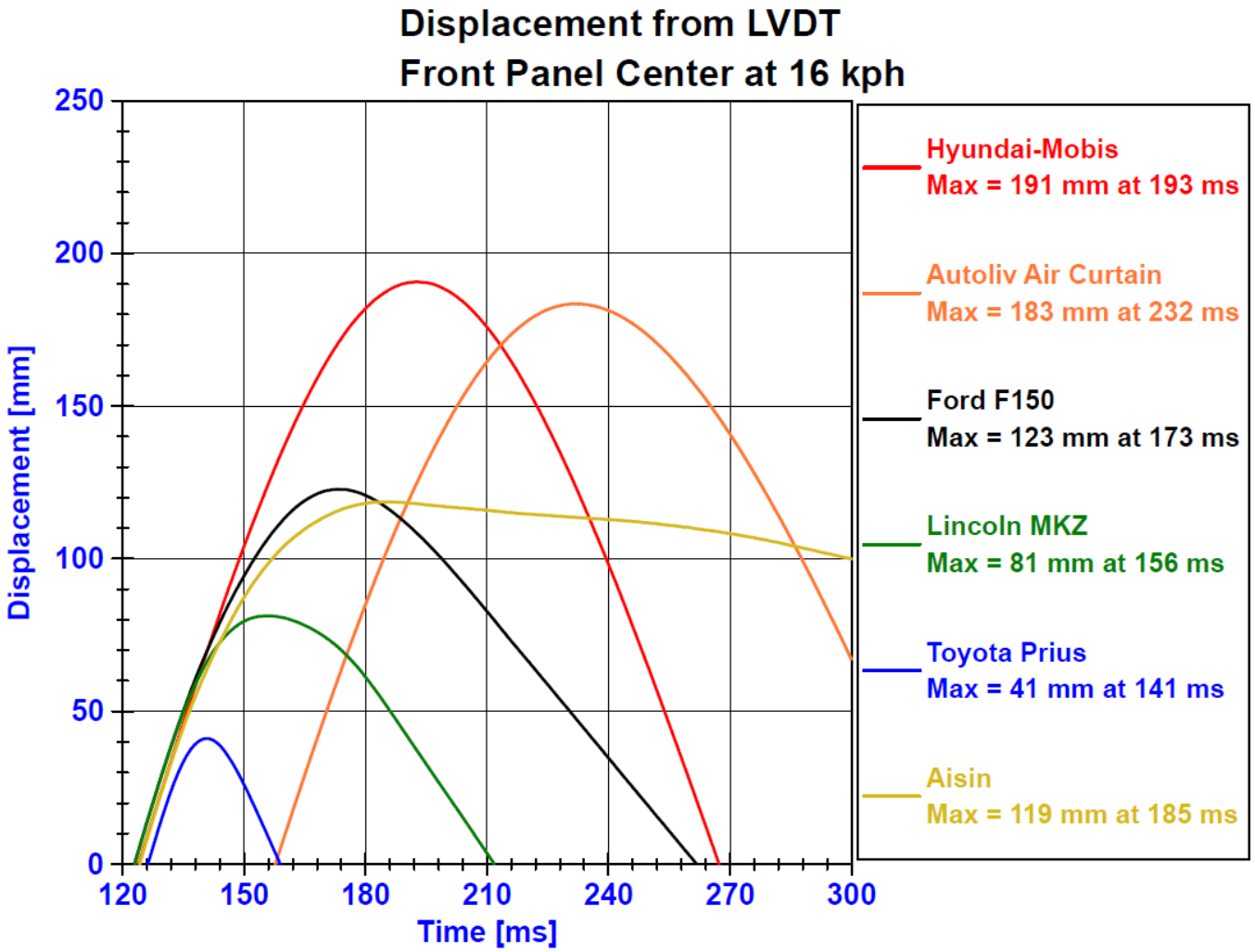
- Similar excursion results between Hyundai and Autoliv on front panel
- Both OPW results, 6 second delay, all Hyundai bags were hand opened, only half of Autoliv were hand opened (indicated with ^)
- Different chamber pattern and inflator, different opening size and bag size (shown to scale above)
- Front glass impacts on Hyundai kept plexiglass on rear panel, Autoliv did not have any plexiglass panels

Force Comparison (All Vehicles)



- Curtain air bags had similar forces and energy to each other
- Curtain air bags had similar forces but higher excursions than laminate movable sunroofs

Excursion Comparison (All Vehicles)



- Air Curtains had the highest ram displacements
- Prius had the smallest displacement
- The Aisin panel detached from the supports

Overall Observations

- Movable panels with good attachment designs can have excursion <100mm
  - MKZ had metal rails, pins and cam
- Air curtains feasible for preventing ejection but still in development
- Roof air curtains produced similar headform forces and higher excursions than laminate movable sunroofs
- All components in load path need to be designed for occupant containment
  - Rail, rail inserts, bonding to glass, glass/plastic strength
- Smaller excursions may lead to higher head and neck forces

Thank You for Your Attention

Data can be found at: Component Test Database (COMDB)
https://www-nrd.nhtsa.dot.gov/database/VSR/com/QueryTest.aspx
Test Numbers for Autoliv tests: c01826 through c01888