Selection of Appropriate Child ATDs for Aviation Child Restraint System Testing

Presented to: Sixth Triennial International Aircraft and Cabin Safety Research Conference
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Date: October 26, 2010
Outline

• Child Restraints for Aircraft Use
• Test Dummies Cited in Aviation Standards
• Test Dummies Cited in Auto Safety Standards
• Test Dummy Selection for Minimum Performance Standards
• Innovative Aviation Unique Child Restraints
• Test Dummy Selection for Research
Child Restraints for Aircraft Use

• **Automotive** CRS (Child Restraint System) have been allowed on aircraft since 1985.

• **Must meet performance/design criteria defined in FMVSS-213.**
  – FMVSS-213 specifies requirements for child restraint systems used in motor vehicles and aircraft.

• **This standard is updated regularly by NHTSA* to reflect safety advancements.**
  – FMVSS-213 last updated August 2005

*NHTSA – National Highway Traffic Safety Administration*
Child Restraints for Aircraft Use

Two approval methods have been used for Aviation Unique CRS:

1) TSO-C100b (references SAE AS5276/1)
   - Reflects testing techniques, technology, and injury criteria cited in FMVSS-213 at the time of publication.
   - Neither have been updated since initial publication.
     - TSO published in 2002
     - AS5276/1 published in 2000
   - Do not have to meet FMVSS-213
Child Restraints for Aircraft Use

Two approval methods have been used for Aviation Unique CRS:

2) Approved by Type Certificate, Supplemental Type Certificate, or 14CFR21.305(d)
   - Must provide an Equivalent Level of Safety to TSO-C100b.
   - Unique minimum performance standards (MPS) are developed for each device.
   - Do not have to meet FMVSS-213
Child Restraints for Aircraft Use

• Since the development of the Aviation Standards for CRS, the automotive standard has been revised significantly.
• CAMI has conducted a review of the revised requirements for potential application to aircraft.
  – Advanced Anthropomorphic Test Dummies (ATD) cited in the revised standard can provide safety benefits for aviation unique CRS.
Test Dummies Cited in Aviation Standards

• ATDs cited in AS 5276/1
  – CAMI Newborn
  – TNO 9-month-old
  – VIP 3-year-old

• These are the same ATDs called out in FMVSS-213 for use up till 2005.
CAMI Newborn

- **Aft facing only**
  - **Construction**
    - Leather skeleton
    - Cast lead or aluminum blocks attached to skeleton to achieve correct mass distribution and limit joint range of motion.
    - Polyurethane foam padding applied over the skeleton to achieve proper shape.
    - Covered in marine canvas laced together.
    - The ATD contains no instrumentation.
  - **Defined in:**
CAMI Newborn

– The CAMI newborn was scaled from a 6-month-old that had been developed at CAMI in 1972 and defined in 49 CFR Part 572, subpart D.

– Evaluation Criteria Produced
  • Angle between the CRS back support surface and vertical shall not exceed 70°.
  • ATD torso shall be retained within the CRS, the Head CG shall not pass the forward-most and top-most points on the CRS surfaces.
TNO 9-month-old

- Aft and forward facing
  - Construction
    - Constructed mainly of polyurethane rubber parts.
    - A single cable runs from the head to the pelvis, and the dummy’s parts are essentially stacked on this cable.
    - A foam insert serves as the abdomen, and the pelvis is made of a ceramic-type material covered in polyurethane.
  - Defined in:

TNO 9-month old

– Evaluation Criteria Produced

• Aft Facing Requirements
  – Maximum value for HIC after head contact is not to exceed 1000.
  – Angle between the CRS back support surface and vertical shall not exceed 70°.
  – ATD torso shall be retained within the CRS, the Head CG shall not pass the forward-most and top-most points on the CRS surfaces.
TNO 9-month old

– Evaluation Criteria Produced (cont.)
  • Forward Facing Requirements
    – Maximum value for HIC after head contact is not to exceed 1000.
    – Chest acceleration shall not exceed 60g’s, except during a cumulative 3 millisecond interval.
    – ATD head shall not pass through a vertical transverse plane 813 mm forward of the seat back pivot axis on the standard seat fixture.
    – ATD knee pivot shall not pass through a vertical transverse plane 915 mm forward of the seat back pivot axis on the standard seat fixture.
VIP 3-Year old

- Forward facing only
  - Construction
    - The VIP (Very Important Person) has steel skeletal components with some aluminum and bronze joints
    - Natural rubber neck
    - Vinyl skin chest jacket covering a separate urethane foam chest flesh
    - Natural rubber lumbar spine
    - Vinyl skin and vinyl foam flesh arms and legs

http://www.ftss.com/crash-test-dummies/children/vip-3-year-old
VIP 3-Year old

– Defined in:
  • 49 CFR Part 572 subpart C adopted in 1979

– Evaluation Criteria Produced
  • Maximum value for HIC after head contact is not to exceed 1000.
  • Chest acceleration shall not exceed 60g’s, except during a cumulative 3 millisecond interval.
  • ATD head shall not pass through a vertical transverse plane 813 mm forward of the seat back pivot axis on the standard seat fixture.
  • ATD knee pivot shall not pass through a vertical transverse plane 915 mm forward of the seat back pivot axis on the standard seat fixture.
Test Dummies Cited in Automotive Safety Standards

- Advanced Test dummies cited in current FMVSS-213 and FMVSS-208 (for out-of-position airbag testing):
  - CAMI newborn (unchanged)
  - CRABI 12-month-old
  - Hybrid-III 3-year-old
CRABI 12-month-old

• Aft and forward facing
  – Construction
    • The CRABI (Child Restraint Air Bag Interaction) design was somewhat based on the Hybrid-III family of dummies, but provides response sensitivity while in a rear facing restraint.
    • Steel skeletal components with a segmented neck and spine. Vinyl skin chest jacket covering a separate urethane foam chest and abdomen

http://www.nhtsa.gov/Research/CRABI+12-Month+Old+Physical+Data
CRABI 12-month-old

– Advantages of Advanced Features
  • Increased size and mass from the 9 month old to a 12 month old will provide a higher level of safety for transitional size occupants.
  • Increased instrumentation capability
    – Head, Chest and Pelvis Accelerations
    – Neck loads, Spine loads, Shoulder Loads and Pubic loads
    – Not all instrumentation is used for CRS evaluation, some are only used for Out-Of-Position Scenario (OOPS) airbag testing
  • The CRABI has increased biofidelity (human like traits) which leads to better prediction of injury.
CRABI 12-month-old

- CRS Evaluation Criteria Produced
  - Aft Facing Requirements
    - Maximum value for HIC36 is not to exceed 1000.
    - Angle between the CRS back support surface and vertical shall not exceed 70°.
    - ATD torso shall be retained within the CRS, the Head CG shall not pass the forward-most and top-most points on the CRS surfaces.
CRABI 12-month-old

- CRS Evaluation Criteria
  Produced (cont)
  • Forward Facing Requirements
    - Maximum value for HIC36 is not to exceed 1000.
    - Chest acceleration shall not exceed 60g’s, except during a cumulative 3 millisecond interval.
    - ATD head shall not pass through a vertical transverse plane 813 mm forward of the seat back pivot axis on the standard seat fixture.
    - ATD knee pivot shall not pass through a vertical transverse plane 915 mm forward of the seat back pivot axis on the standard seat fixture.
Hybrid-III 3-year-old

• **Forward facing only**
  – Construction
    • Similar design features and construction as the Hybrid-III dummy family
    • The dummy was designed to be used while properly restrained in a CRS as well as out of position so the pelvis is made to reflect various postures.

http://www.nhtsa.gov/Research/HYBRID+III+3-Year+Old+Physical+Data#features
Hybrid-III 3-year-old

– Advantages of Advanced Features
  • Internal structure is more human-like in areas that interact with restraint systems.
  • Increased instrumentation. Has the potential for up to 50 channels to be measured.
    – Not all instrumentation is used for CRS evaluation, some are only used for OOPS airbag testing.
  • The Hybrid III also has increased biofidelity which leads to better prediction of injury.
    – Crucial components such as the head, neck and thorax were designed to meet specific biofidelity corridors.
Hybrid-III 3-year-old

– CRS Evaluation Criteria Produced
  • Maximum value for HIC36 is not to exceed 1000.
  • Chest acceleration shall not exceed 60g’s, except during a cumulative 3 millisecond interval.
  • ATD head shall not pass through a vertical transverse plane 813 mm forward of the seat back pivot axis on the standard seat fixture.
  • ATD knee pivot shall not pass through a vertical transverse plane 915 mm forward of the seat back pivot axis on the standard seat fixture.
Test Dummy Selection for
Minimum Performance Standards

• FMVSS-213 and TSO-C100b Child Restraint Systems are substantially similar in construction.
  – Protective shell construction
  – Integral restraint system
  – Forward and aft-facing configurations

• Therefore the improved injury assessment capabilities provided by the CRABI 12-month-old and Hybrid III 3-year-old should provide the same safety benefits for the aviation tests as automotive tests.
Innovative Aviation Unique Child Restraint Systems

- CAMI is planning to conduct research to develop a Minimum Performance Standard suitable for evaluation of innovative Aviation Child Safety Devices (ACSD)
- These devices may load the occupant differently than when seated in a conventional rigid shell type CRS.
- ATDs are needed that can assess the injury risks associated with these unique loading conditions.
Upper Torso Harnesses

• Upper torso harnesses utilize the existing aircraft lap belt which may not have optimum geometry for restraint of the smallest occupants.

• An ATD that interacts with the belt system in a biofidelic manner is needed to thoroughly assess the safety of these types of systems.
Pre-Inflated Restraints

- Systems that restrain the child with a forward supporting surface may produce significant chest and abdominal loading.
- An ATD that interacts with the support surface in a biofidelic manner and can measure injury criteria associated with that interaction is needed.
Large Forward Facing Restraints

- Some systems may be able to offer improved safety for occupants larger than currently addressed by TSO-C100b.
- A larger ATD than is currently specified in the aviation standards is needed to provide the appropriate loading condition.

Innovint SkyKids CRS
Test Dummy Selection for Research

- Candidate ATD’s for measuring safety of the unique loading cases.
  - TNO Q 1 year old
  - Hybrid-III 3-yr old
  - Hybrid-III 6-yr old
TNO Q series 1-year-old

• Offers a more biofidelic pelvis and clavicle geometry than the CRABI. Should provide a more human-like interaction with restraint systems.

• Chest deflection instrumentation will allow direct assessment of interactions with forward support surfaces.
Q1 and CRABI Pelvic Comparison

- Blue is CRABI pelvis
- Grey is the TNO Q series 1-year-old ATD Pelvis

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<tr>
<th>Images courtesy of FTSS</th>
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<tr>
<td>Red is CRABI</td>
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<td>Grey is the TNO Q series</td>
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<td>1-year-old</td>
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Q1 and CRABI Clavicle Comparison

Q1 Clavicle Assembly

CRABI Clavicle Assembly
Hybrid-III 3-year-old

- Iliac crest load cell will provide an indication of whether the lap belt is interacting properly with the pelvis.
- Superior torso biofidelity and chest deflection instrumentation will allow direct assessment of interactions with forward support surfaces.

Anterior Superior Iliac Spine (ASIS) Load Cells

Picture from the Hybrid III 3 year old PADI manual
Hybrid-III 6-year-old

- Cited in FMVSS-213 for evaluation of CRS that can accommodate occupants from 18 to 22.7 Kg. or greater than 1100 mm in stature.
- Has the same advanced biofidelity and instrumentation advantages as the 3-year-old size Hybrid-III.
- Defined in 49 CFR Part 572 subpart N.
Questions

TNO Q1

Hybrid III 3 year old

Hybrid III 6 year old