Selection of Appropriate Child ATDs for Aviation Child Restraint System Testing

Federal Aviation Administration

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Outline

- **Child Restraints for Aircraft Use**
- **Test Dummies Cited in Aviation Standards**
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- **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:
    - 49 CFR Part 572, subpart K adopted in 1993.

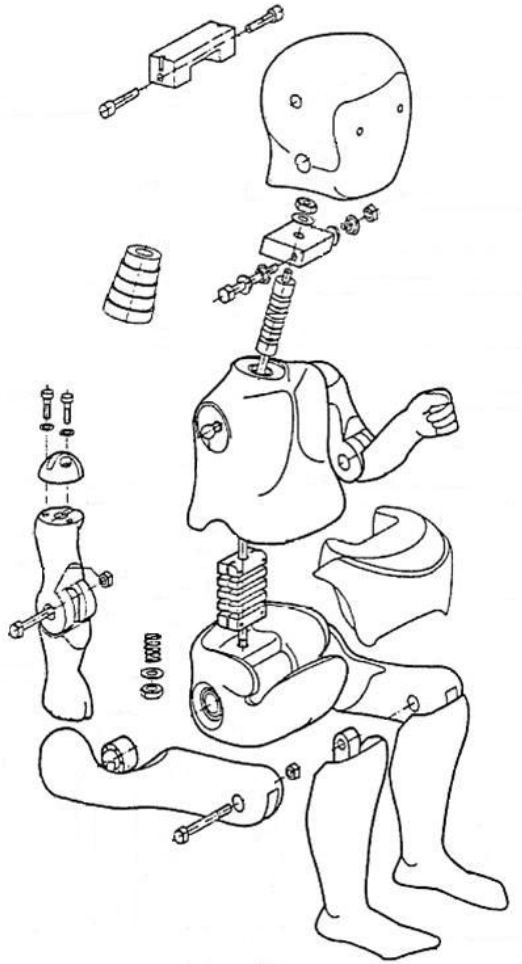
CAMI Newborn

– 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:
    - 49 CFR Part 572 subpart J adopted in 1991



Exploded View of the TNO P3/4

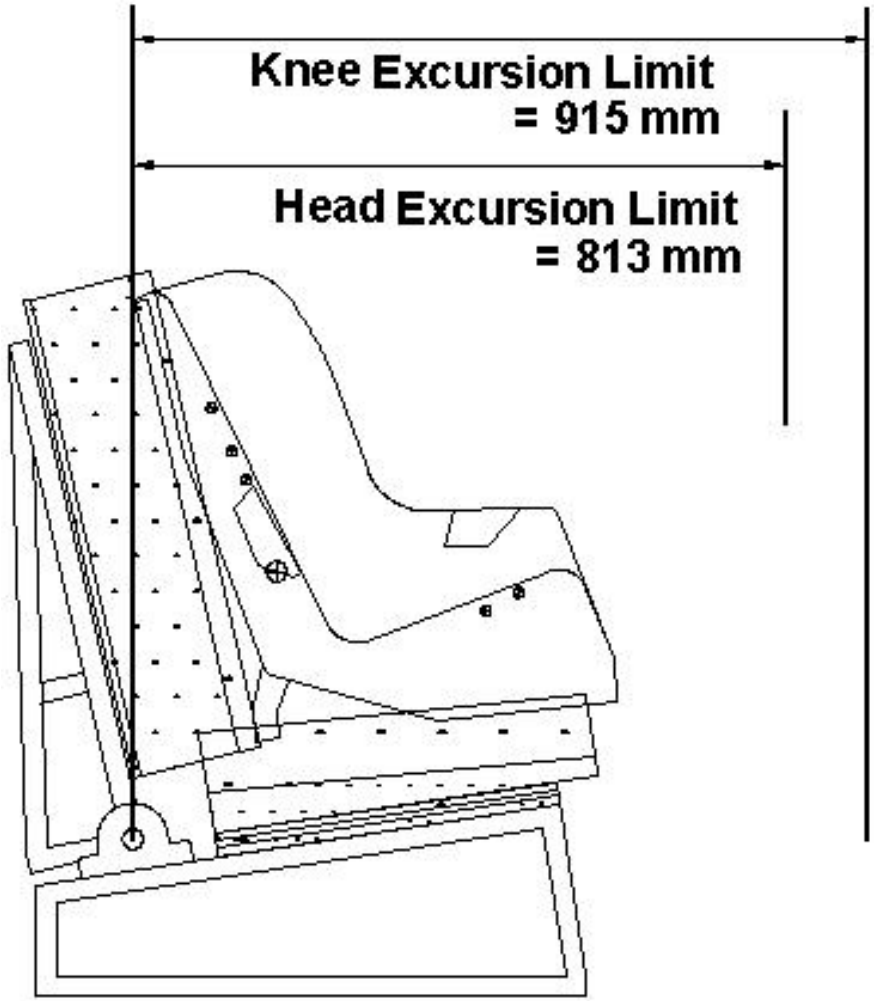
Hagedorn, A.V. and Pritz, H.B., " Evaluation of the CRABI 12-Month-Old Infant Dummy and Its Comparison With the TNO P3/4," NHTSA Docket #99-5156, February, 1999.

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

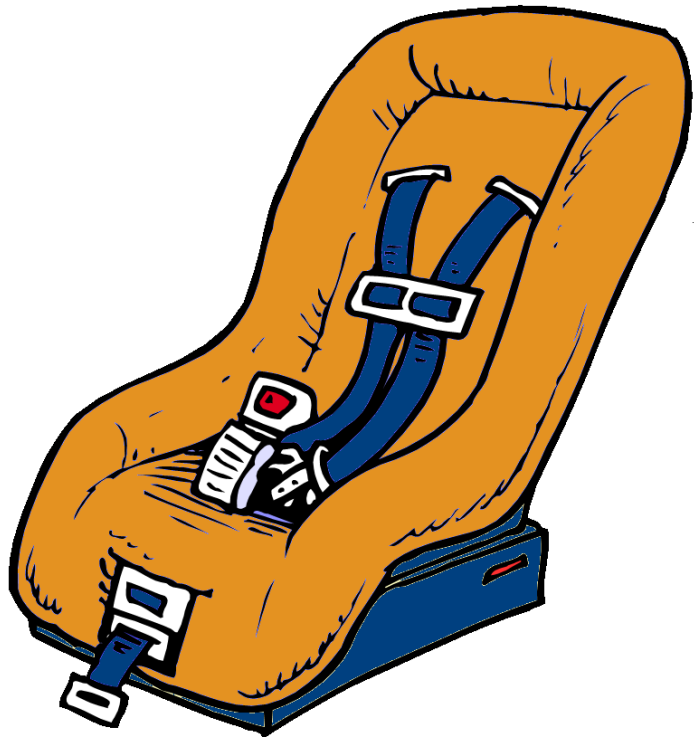
- Increased size and mass from the 9 month old to a 12 month old will provide a higher level of safety for transitional size occupants.
- Increased instrumentation capability
  - Head, Chest and Pelvis Accelerations
  - Neck loads, Spine loads, Shoulder Loads and Pubic loads
  - Not all instrumentation 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.**

AmSafe CAReS

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.**

Luftikid

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

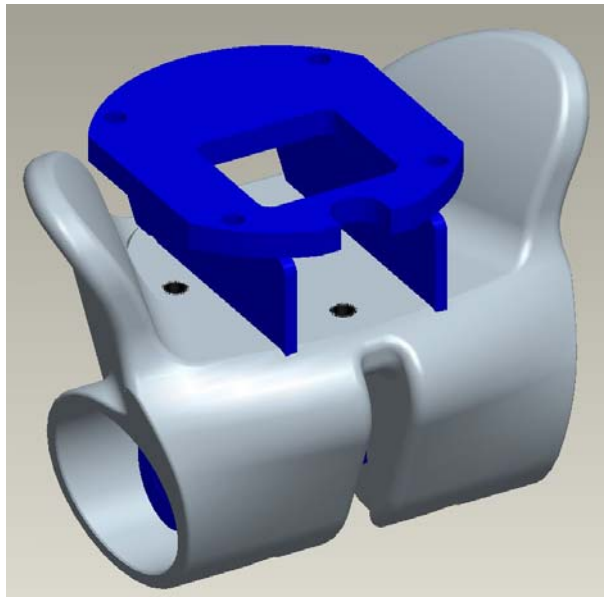
- **Candidate ATD's for measuring safety of the unique loading cases.**
  - TNO Q 1 year old
  - Hybrid-III 3-yr old
  - Hybrid-III 6-yr old

TNO Q series 1-year-old

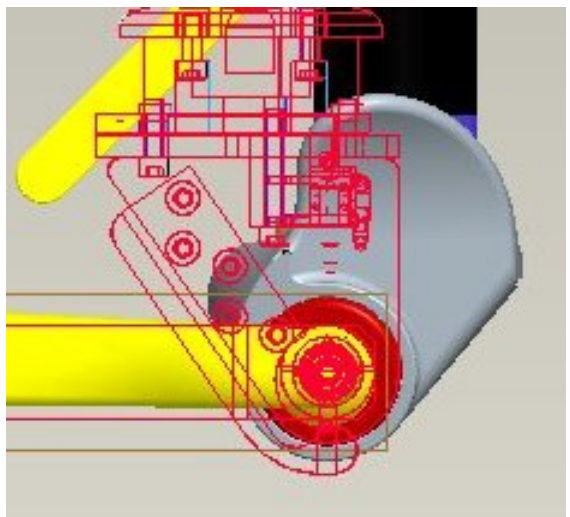
- **Offers a more biofidelic pelvis and clavicle geometry than the CRABI. Should provide a more human-like interaction with restraint systems.**
- **Chest deflection instrumentation will allow direct assessment of interactions with forward support surfaces.**

Q1 and CRABI Pelvic Comparison

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

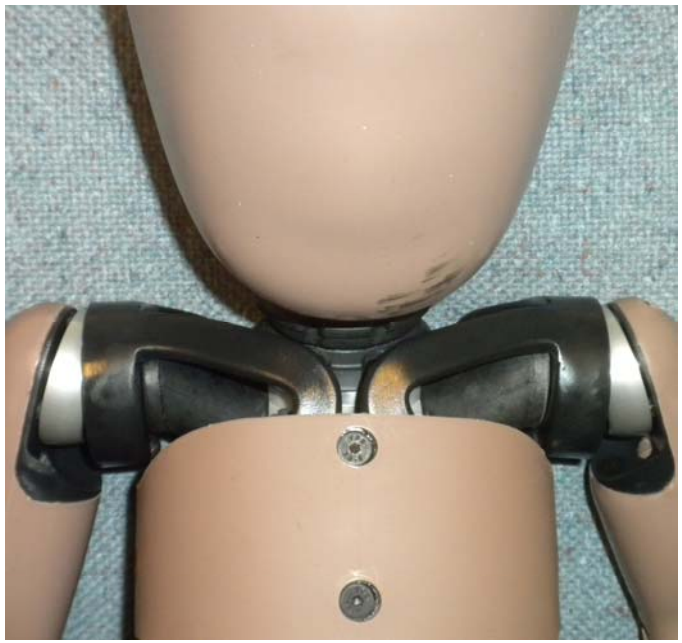


- **Red is CRABI**
- **Grey is the TNO Q series 1- year old**

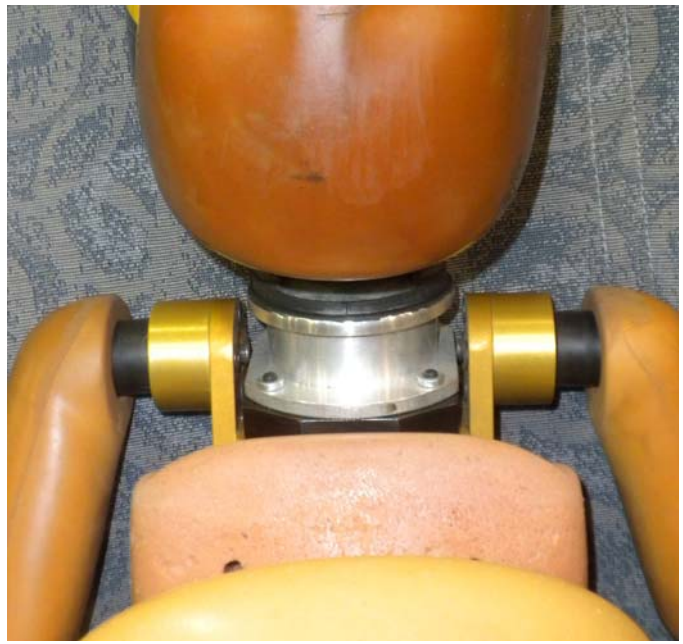


Images courtesy of FTSS

Q1 and CRABI Clavicle Comparison



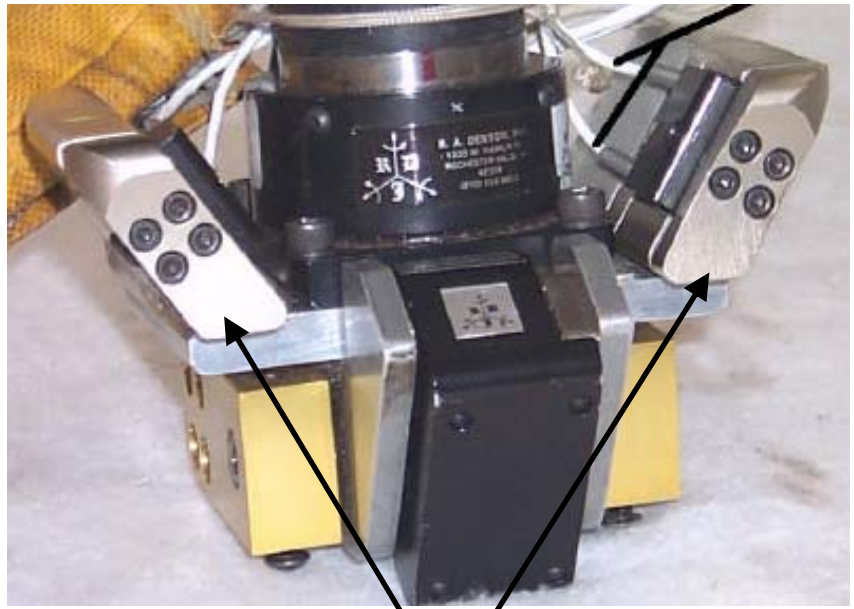
Q1 Clavicle Assembly



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