Automotive Child Restraint types and their installation in Transport Category Aeroplanes

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Australian situation

- Australian Standard for Child Restraints in Motor Vehicles has required top tether use since 1975.
- CASA requires installation of CRS in accordance with manufacturer’s instructions – installation in aircraft requires top tether use for Australian CRS.
Australian Aviation Situation

• CAR 251(1) “….. seat belts shall be worn by all crew members and passengers…..”

• CAR 251(3) “CASA may direct that a type of safety harness….. be worn in place of a seat belt…..”

• CAO 20.16.3 Para.13.2(1) “An infant may be carried in the arms or on the lap of an adult passenger, in a bassinet or in an infant seat…..”

• CAAP 235-2(1) Para 2.1 “An infant carried in the arms of an adult passenger (lap held) must be restrained…..”
The Research

- Concentrated on dynamic performance.
- Focus on Australian indigenous configuration issues.
- Results applicable to worldwide operations.
The Research

1. Top Tether contribution to dynamic performance.
2. Alternative to top tether.
3. ISOFIX type CRS.
Test Setup

- Impact-with-Rebound Sled
- TSO-C39b Airline Double Economy Class Seat with breakover limiting devices.
- P series child ATDs
- Hybrid III (Automotive) Adult ATDs
- Two CRS per test shot
Test Criteria

- FAA TSO-C100b ‘Child Restraint Systems’
  - Test severity
  - Instrumentation
  - Pass/fail criteria, and
  - ATD and ATD installation
  - Supplemental pass/fail criteria
Top Tether

- Doubles installation effort.
- Bulkhead anchors not practical.
- Is it effective?
Belt Angles
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## Top Tether test results

<table>
<thead>
<tr>
<th></th>
<th>Max. Head Acceleration (3ms clip)</th>
<th>HIC36</th>
<th>Max. Head Excursion</th>
<th>Max. Upper Thorax Acceleration (3ms clip)</th>
<th>Max. CRS displacement (@ belt path)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rear facing – P3/4</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safe-n-Sound</td>
<td>49.2g</td>
<td>280</td>
<td></td>
<td>39.7g</td>
<td></td>
</tr>
<tr>
<td>IGC Gosafe</td>
<td>50.1g</td>
<td>295</td>
<td></td>
<td>53.0g</td>
<td>~6.5 in (165 mm)</td>
</tr>
<tr>
<td><strong>Forward facing – P3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safe-n-Sound</td>
<td>80.8g</td>
<td>499</td>
<td>35.5 in (902 mm)</td>
<td>53.0g</td>
<td>~12 in (305 mm)</td>
</tr>
<tr>
<td>IGC Gosafe</td>
<td>113.9g</td>
<td>944</td>
<td>36.7 in (932 mm)</td>
<td>42.9g</td>
<td>~13 in (330 mm)</td>
</tr>
</tbody>
</table>
Belt Angles
Alternate restraint mechanism

- Remove the use of the Top Tether.
- Add horizontal restraint mechanism.
- Improve CRS performance.
- Part already available on every aircraft.
Alternate restraint mechanism
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## Extension Belt test results

<table>
<thead>
<tr>
<th>Forward facing – P3</th>
<th>Max. Head Acceleration (3ms clip)</th>
<th>HIC36</th>
<th>Max. Head Excursion</th>
<th>Max. Upper Thorax Acceleration (3ms clip)</th>
<th>Max. CRS displacement (@ belt path)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGC Gosafe (lap belt only)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>44.6g</td>
<td>-</td>
</tr>
<tr>
<td>IGC Gosafe (Lap belt and extension belt)</td>
<td>58.8g</td>
<td>501</td>
<td>33.6 in (853 mm)</td>
<td>37.8g</td>
<td>~10 in (254 mm)</td>
</tr>
</tbody>
</table>
Top Tether

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Extension Belt
ISOfix

- Aircraft lap belt not used.
- CRS mechanically fastened to seat.
- Rigid link.
- Two 40mm long Ø6mm round bars in seat bight.
ISOfix
ISOfix Restraints
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## ISOfix test results

<table>
<thead>
<tr>
<th>Model</th>
<th>Max. Head Acceleration (3ms clip)</th>
<th>HIC36</th>
<th>Max. Head Excursion</th>
<th>Max. Upper Thorax Acceleration (3ms clip)</th>
<th>Max. CRS displacement (@ belt path)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Britax 'Cosy-Tot' ISOfix (RF) P3/4</td>
<td>57.2g</td>
<td>436</td>
<td></td>
<td>35.2g</td>
<td>~1.5 in (38mm)</td>
</tr>
<tr>
<td>Britax ‘Duo-Plus’ ISOfix (FF) – P3</td>
<td>63.6g</td>
<td>276</td>
<td>27.0 in (686 mm)</td>
<td>32.4g</td>
<td>~2.5 in (64 mm)</td>
</tr>
</tbody>
</table>
Top
Tether

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ISOfix
Comparative results – Rear facing

- **HIC**
  - Limit: 1000
  - Safe-n-Sound: 280
  - IGC Gosafe: 295
  - Britax Cosy-Tot (ISOfix): 436

- **Chest Acceleration (g)**
  - Limit: 60
  - Safe-n-Sound: 39.7
  - IGC Gosafe: 53
  - Britax Cosy-Tot (ISOfix): 35.2

- **CRS Displacement (in)**
  - Limit: 7
  - Safe-n-Sound: 6.5
  - IGC Gosafe: 1.5
Comparative results – Forward facing

**HIC**

- Safe-n-Sound: 499
- IGC Gosafe: 944
- IGC Gosafe (extension belt): 501
- Britax Duo-Plus (ISOfix): 276

**Head Excursion (in)**

- Safe-n-Sound: 35.5
- IGC Gosafe: 36.7
- IGC Gosafe (extension belt): 33.6
- Britax Duo-Plus (ISOfix): 27

**Chest Acceleration (g)**

- Safe-n-Sound: 53
- IGC Gosafe: 42.9
- IGC Gosafe (extension belt): 37.8
- Britax Duo-Plus (ISOfix): 32.4

**CRS Displacement (in)**

- Safe-n-Sound: 12
- IGC Gosafe: 13
- IGC Gosafe (extension belt): 10
- Britax Duo-Plus (ISOfix): 2.5
ISOfix modification
ISOfix modification
ISOfix modification
ISOfix modification
ISOfix concerns

- Failure of the CRS due to:
  - Overload of the lower anchorage from persons knees seated behind.
  - Pressure applied via the additional seat back loading from impact from behind.

- Increased injury to persons seated behind due to:
  - Femur compression/localised knee damage from interaction with the lower anchorage.
  - Increased HIC from reduced seat back breakover.
Adult/ISOfix interaction

- Most concerns not realised
  - Knees of 50\textsuperscript{th} percentile ATD restrained before reaching lower anchorage and lower limbs pass below lower anchorage.
  - HIC below limits.
  - Child ATD injury levels not varied.
- Adult head rotation severe
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### ‘ISOfix with rear Pax’ test results

<table>
<thead>
<tr>
<th></th>
<th>Max. Head Acceleration (3ms clip)</th>
<th>HIC36</th>
<th>Max. Upper Thorax Acceleration (3ms clip)</th>
<th>Max Femur Load</th>
<th>Max. CRS displacement (@ belt path)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Child ATD</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Britax ‘Cosy-Tot’ ISOFix (RF)- P3/4</td>
<td>53.6g</td>
<td>419</td>
<td>41.0g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Britax ‘Duo-Plus’ ISOFix (FF) – P3</td>
<td>36.0g</td>
<td>148</td>
<td>34.0g</td>
<td></td>
<td>~3 in (165 mm)</td>
</tr>
<tr>
<td><strong>Adult ATD</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hybrid III behind Britax ‘Cosy-Tot’ ISOFix (RF)- P3/4</td>
<td>92.2g</td>
<td>813</td>
<td>25.3g</td>
<td>2.11,1.21 kN (957, 549 lbs)</td>
<td></td>
</tr>
<tr>
<td>Hybrid III behind Britax ‘Duo-Plus’ ISOFix (FF) – P3</td>
<td>90.2g</td>
<td>902</td>
<td>26.4g</td>
<td>1.30,1.89 kN (590, 857 lbs)</td>
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</tbody>
</table>
Recommendations

• Infants and small children should travel in their own seat, in an appropriately sized and fitted child restraint system.
• Revisions to CASA’s Advisory material.
• Minimum standards for lower anchorages in aircraft seating need to be developed.
• ISOfix further testing:
  • Retesting with neck instrumentation in adult ATD.
  • Retesting with 95th percentile male ATD.
  • Similar assessment for LATCH CRS.
Recommendations

• Airline encouraged to fit lower anchorages to window seats, and the centre seats of twin aisle aircraft, were there is no risk of injury to anybody seated behind, i.e in front of bulkheads, lavs/galleys, floor level exits or floor mounted rear facing cabin crew positions.

Questions?

"I don't know about you, but I'm not too wild about these new child restraints."
CALVIN and HOBBES

YOU KNOW, DAD, IT DISTURBS ME THAT THIS WAGON HAS NO SEAT BELTS AND WOULDN'T SURVIVE A 30 MPH IMPACT WITH A STATIONARY OBJECT.