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Analysis of Child Restraint System (CRS) Compatibility with Aircraft Seats

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12. Abstract

Child restraint systems (CRS or child safety seats) are primarily designed for use in automotive vehicles. The Federal Aviation Administration (FAA) encourages the use of CRS approved for use on aircraft. The securement of a CRS to an aircraft seat can be challenging due to physical space restrictions. If caregivers face too many barriers when attempting to fly with a CRS, they might choose a less safe option, such as holding their infant or securing the infant or child in an aircraft seat using only the FAA-approved seat belt (usually a lap belt only). The broad objective of this work is to quantify compatibility concerns between CRS and aircraft seats and seat belts to ultimately facilitate higher rates of CRS use on aircraft.

The physical dimensions of aircraft seats (n=8) were obtained through collaboration with seat manufacturers. Seats included economy and premium class in regional jet, narrow-body, and wide-body aircraft. The dimensions of various CRS (n=64) were compiled from previous studies, including infant, convertible, combination, and all-in-one CRS types. Compatibility between CRS and aircraft seats was predicted in terms of seat width, seat cushion angles, seat cushion length, adjustable headrest height from seat cushion, depth (fore/aft space between rows), and seat belt buckle location. Aircraft seat dimensions were also compared to automotive vehicle seat dimensions (n=111) collected during previous studies, so that broad comparisons could be made across the seating environments. Aircraft seat dimensions were also compared to the Federal Motor Vehicle Safety Standard (FMVSS) 213 inversion bench and the aircraft/CRS compatibility guidance within SAE International Aerospace Recommended Practice (ARP) 4466.

The width of several aircraft seats could not accommodate the width of most CRS, especially larger types of CRS (convertible, combination, and all-in-one) in regional jet and narrow-body aircraft. Aircraft seat cushion angles were more horizontal than those in vehicles. The seat back angle with respect to seat cushion angle matched forward-facing (FF) CRS reasonably well, suggesting a good fit in terms of angle. Seat cushion length in aircraft is shorter than the length needed to accommodate many rear-facing (RF) CRS. The depth of aircraft seats (fore/aft space between rows) is similar to that of vehicles with the front row slider track in the fully rearward position. This may cause difficulty securing large CRS in RF mode. Aircraft seat belt buckle hardware often sits within the belt path of many CRS. The FMVSS 213 inversion bench has a steeper seat pan angle and a more acute angle between seat cushions compared to the aircraft seat dimensions collected in this study. The aircraft seat dimensions matched the guidance in SAE ARP4466 well, and the recommended dimensions would accommodate some of the smaller CRS, but not the larger CRS. The results of this study provide benchmark data for manufacturers and elucidate potential difficulties for manufacturers, regulators, safety advocates, and caregivers to consider.

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List of Abbreviations

Acronym	Abbreviation Explained
ACSD	Aviation Child Restraint Device
CChIPS	Center for Child Injury Prevention Studies
CRS	Child Restraint System
FF	Forward-Facing
RF	Rear-Facing
FMVSS	Federal Motor Vehicle Safety Standards
NHTSA	National Highway Traffic Safety Administration
SAE	SAE International

Abstract/Executive Summary

Child Restraint Systems (CRS or child safety seats) are primarily designed for use in automotive vehicles. The Federal Aviation Administration (FAA) encourages the use of CRS that are approved for use on aircraft. The securement of a CRS to an aircraft seat can be challenging due to physical space restrictions. If caregivers face too many barriers when attempting to fly with a CRS, they might choose a less safe option, such as holding their infant or securing the infant or child in an aircraft seat using only the FAA-approved seat belt (usually a lap belt only). The broad objective of this work is to quantify compatibility concerns between CRS and aircraft seats and seat belts to ultimately facilitate higher rates of CRS use on aircraft.

The physical dimensions of aircraft seats (n=8) were obtained through collaboration with the SAE Aircraft Seat Committee. Seats included economy and premium in regional jet, narrow-body, and wide-body aircraft. The corresponding dimensions of various CRS (n=64) were compiled from previous studies. Compatibility between CRS and aircraft seats was predicted in terms of seat width, seat cushion angles, seat cushion length, headrest height from the seat cushion, depth (fore/aft space between rows), and seat belt buckle location. Aircraft seat dimensions were also compared to automotive vehicle seat dimensions (n=111) collected during previous studies, allowing for broad comparisons across seating environments. Aircraft seat dimensions were also compared to the Federal Motor Vehicle Safety Standard (FMVSS) 213 inversion bench and the aircraft/CRS compatibility guidance within SAE International Aerospace Recommended Practice (ARP) 4466.

The width of several aircraft seats could not accommodate the width of many CRS, especially larger types of CRS in regional jets or narrow-body aircraft. Aircraft seat cushion angles were more horizontal than those in vehicles. The seat back angle with respect to the seat cushion angle matched forward-facing (FF) CRS reasonably well, suggesting a good fit in terms of angle. Seat cushion lengths in aircraft are shorter than the length needed to accommodate many rear-facing (RF) CRS. The depth of aircraft seats (fore/aft space between rows) is similar to that of vehicles with the front row slider track in the fully rearward position. This may cause difficulty securing large CRS in RF mode. Aircraft seat belt buckle hardware often sits within the belt path of many CRS. The FMVSS 213 inversion bench has a steeper seat pan angle and a more acute angle between seat cushions compared to the aircraft seat dimensions collected in this study. The aircraft seat dimensions matched the guidance in SAE ARP4466 well, and the recommended dimensions would accommodate some of the smaller CRS but not the larger CRS. The results of this study provide benchmark data for manufacturers and elucidate potential difficulties for manufacturers, regulators, safety advocates, and caregivers to consider.

Introduction

According to the Federal Aviation Administration (FAA), the safest place for your child under the age of two on a U.S. airplane is in an approved child restraint system (CRS) or device and not held on a lap (FAA 2025). All CRS must successfully pass the FMVSS 213 inversion test to be approved for use in commercial aircraft in the U.S. The inversion test uses a simulated aircraft passenger seat with "any Federal Aviation Administration approved aircraft safety belt" (NHTSA 2023). The securement of a CRS on an aircraft seat can be challenging due to physical space restrictions and aircraft seat belt characteristics. Caregivers might view these challenges as a deterrent to CRS use on aircraft and choose a less safe option, such as holding their infant (who has not reached their second birthday) on their lap or buckling their small child into the adult lap belt on an adjacent seat. Knowledge about the dimensions and features of the FMVSS 213 inversion seat and belt(s) is also critical for manufacturers, as they must consider this apparatus when optimizing CRS for aircraft use. Overall, more information is needed for both manufacturers and consumers to minimize the risk of difficulty when securing a CRS into an aircraft seat. Improved compatibility could encourage more caregivers to choose this safest travel option for their children.

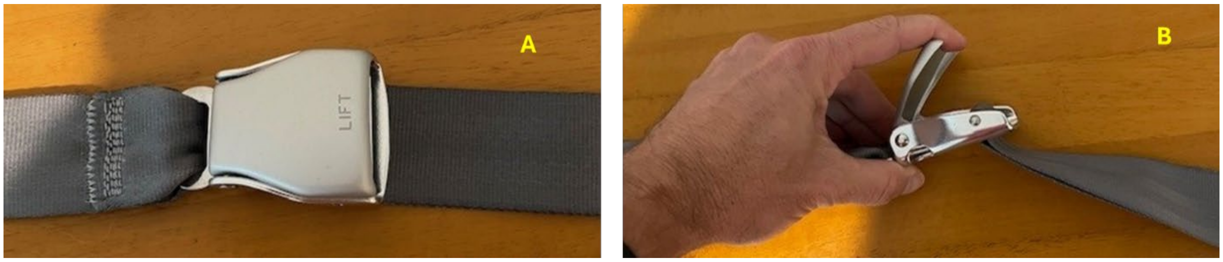
The size of aircraft seats varies across manufacturers and aircraft types. Caregivers often must choose CRS models carefully to increase the odds of a proper fit into aircraft seats. Some families report purchasing smaller, narrower CRS specifically for air travel. Other families may not have access to information about the size of the aircraft's seats in advance of their trip and may be frustrated when they find their CRS does not fit.[1] There is also the possibility of utilizing an Aviation Child Safety Device (ACSD), which has a different approval process. ACSDs were not evaluated as part of this study. A variety of CRS types are allowed on aircraft, including:

- **Infant/rear-facing (RF)-only CRS**: These CRS typically have a base that separates from the seat/child carrier portion. The carrier portion can be secured with or without the base. The CRS can only be secured in the RF orientation.
- **Convertible CRS**: These CRS can be installed in either the RF or forward-facing (FF) orientation and typically have separate belt paths for each securement mode.
- **3-in-1 CRS**: These CRS can be used in RF, FF, or booster mode. Booster mode is prohibited on aircraft (FAA 2015, AC 120-87C).
- **Combination CRS**: These CRS can be used in FF or booster mode. Booster mode is prohibited on aircraft (FAA 2015, AC 120-87C).
- **Aviation Child Safety Device (ACSD)**: A device designed to be used only onboard aircraft to support a child in an aviation seat. ACSDs are not approved for automotive use.

[1] Although the FAA requires commercial air carriers to list on their websites the width of the narrowest and widest passenger seats in each class of service for each airplane make, model and series they operate, this information can be difficult to find. *See* 14 CFR 121.311(k).

Aircraft seat belt designs can also pose a challenge for CRS securements. The buckle of an aircraft seat belt is often located in the center of the two lengths of webbing. The buckle often sits near the top or center of an adult passenger's lap. This differs from a seat belt buckle in a vehicle, which is typically anchored on a short buckle stalk on the passenger's side. For CRS securements, aircraft seat belt buckles must route through the CRS belt path. The size and inflexibility of the buckle hardware can make tight securements difficult when the hardware must navigate the curves of the belt path. Buckles or thick webbing routed through the base of an infant CRS can prevent the carrier portion of the CRS from locking into its base. Some aircraft seat belt buckles have release mechanisms that require a metal plate to be pulled upward to a 90-degree angle from the rest of the buckle (Figure 1). These seat belts can be rendered impossible to unbuckle when the buckle has been routed through a narrow CRS belt path, and there is not enough clearance to lift the release plate. If this were to occur, there would be delays in deplaning the aircraft, and aircraft maintenance may need to be called to remove the belt from the seat. The placement of aircraft buckles also presents a comfort concern: A child might be seated directly on top of the belt buckle when it routes between the CRS shell and the fabric cover of the seating surface.

Figure 1: Typical aviation seat belt with lift latch, closed (A) and open to 90 degrees (B).



An SAE International Aerospace Recommended Practice (ARP) document issued in 1997 (SAE ARP 4466) and subsequently cancelled in 2024 set forth guidance for dimensional compatibility of CRS and passenger seat systems in civil transport airplanes (SAE ARP 4466B). It contains recommendations that a passenger seat cushion should fully support the base of a CRS that is 380 mm wide and 410 mm deep. The aircraft seat should provide at least 410 mm of clearance between armrests and a seat pitch of 760 mm. It includes recommendations for seat belt geometry, including the ability of the buckle to pass through a rectangular opening measuring 40 mm by 80 mm (SAE ARP 4466). CRS have increased in size over the past several decades to accommodate children of higher heights and weights over a broader range of ages. The data used in SAE ARP 4466 do not represent the current generation of CRS; therefore, it is important to update compatibility analyses using modern CRS criteria.

The broad objective of this work is to quantify compatibility concerns between CRS, aircraft seats, and seat belts to facilitate higher rates of CRS use on aircraft. The specific aims are to: 1) Survey the physical dimensions and seat belt characteristics of modern commercial aircraft, 2) Compare the aircraft seating characteristics to the physical characteristics of modern CRS to identify issues with compatibility, 3) Compare aircraft seat dimensions to modern vehicle seat dimensions, the

FMVSS 213 inversion bench, and SAE ARP 4466 guidelines to quantify similarities and differences.

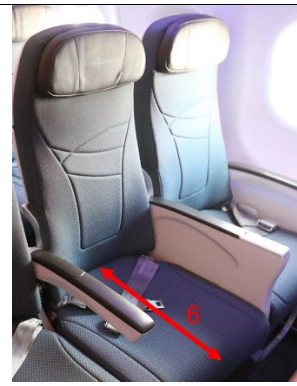
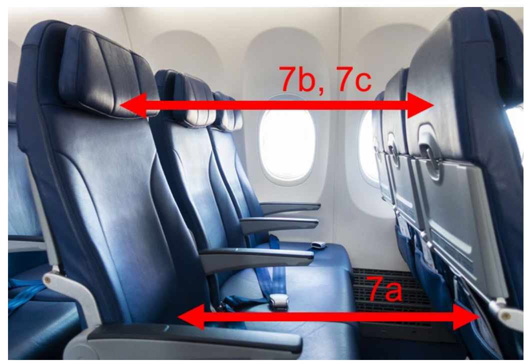
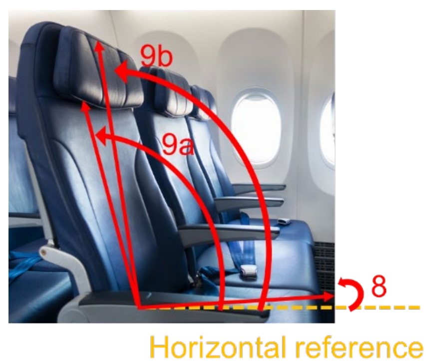
Materials and Methods

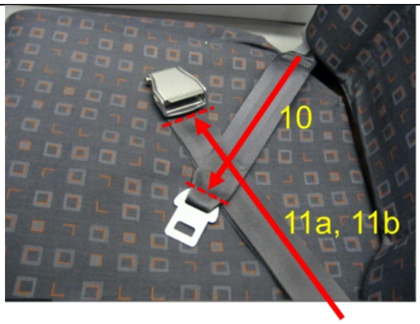
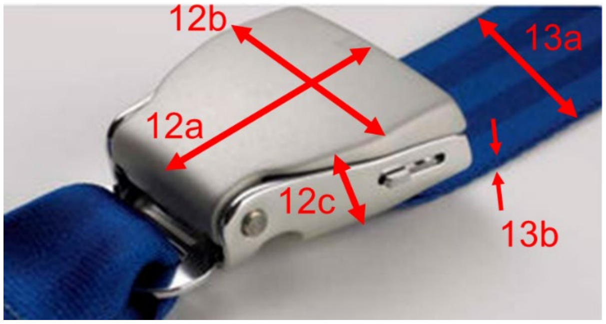
Aircraft Seat Dimensions

The physical dimensions of aircraft seats were obtained through collaboration with the SAE Aircraft Seat Committee. Project leaders presented the goals and methods of the study at a virtual meeting of the committee. Representatives from several major aircraft seat manufacturers were requested to provide data on their company's seats. The majority of measurements were garnered from computer-aided design (CAD) models of the aircraft seats. Meeting attendees were given a spreadsheet with instructions on which dimensions to collect and how to measure each. The following measurements were requested for each unique type of seat the company manufactures:

Table 1: Measurements requested from aircraft seat manufacturers.

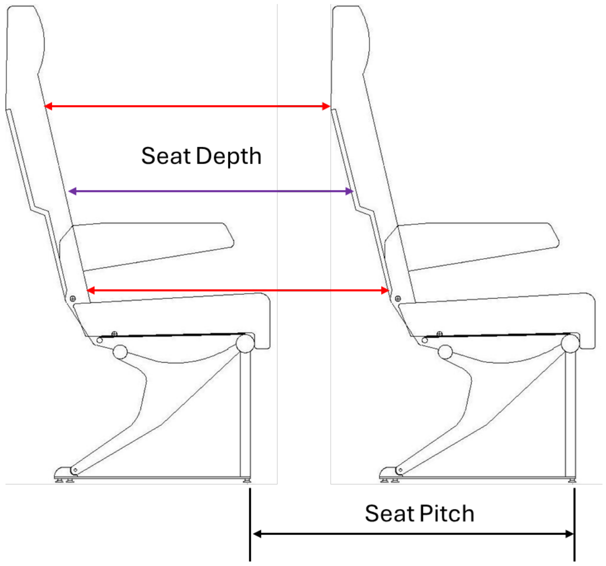
#	Description	Photo
1	Width between armrests, narrowest point	
2	Can armrests be raised? (Yes/No)	
3a	Height from seat cushion to top of armrest, near seat bight	
3b	Height from seat cushion to top of armrest, near edge of seat	
4	Height from seat cushion to bottom of headrest, along the recline of seat back	
5	Height from seat cushion to top of seat, along the recline of seat back	
6	Length of seat cushion, along	

	centerline	
7	Seat depth (fore/aft clearance space) used for basis of measurements 7a, b & c	
7a	Fore/aft clearance space available, along bottom of seat cushion	
7b	Fore/aft clearance space available, approximately halfway up seat	
7c	Repeat 7b with front seat fully reclined	
8	Angle of seat cushion from horizontal	
9a	Angle of seat back from horizontal, underneath headrest	
9b	Angle of seat back from horizontal, over top of headrest	
10	Seat belt webbing length, from seat cushion to bottom part of latch plate	
11a	Seat belt webbing length, from seat cushion to bottom part of buckle, length fully shortened	

11b	Seat belt webbing length, from seat cushion to bottom part of buckle, length fully extended	
12a	Length of buckle at thickest point	
12b	Width of buckle at thickest point	
12c	Height of buckle at thickest point	
13a	Width of seat belt webbing	
13b	Thickness of seat belt webbing	

A note on terminology: *Seat pitch* is defined as the distance from a hard point on the seat to the equivalent hard point on the seat installed forward. This distance can vary between aircraft as well as within aircraft. *Seat depth* is related and dependent on the seat pitch but also is dependent on the seat design, such as cushioning and contouring of the seat back (Figure 2).

Figure 2: Depiction of seat depth (fore/aft clearance space between seats) and pitch (distance between identical points on the seats from row to row).



Data were submitted for passenger seats used in economy and premium classes in regional jet, narrow-body, and wide-body aircraft (Table 2). Two major aircraft seat manufacturers provided data to the researchers. In total, data from eight unique aircraft seats were obtained.

Table 2: Aircraft seats for which dimensional data were obtained.

Seat #	Manufacturer	Aircraft Type	Seat Class	Model	Seat Pitch (cm)
1	A	Regional Jet	Economy	Model 1	76.2
2	B	Narrowbody	Economy	Model 3, STD	71.1
3	B	Narrowbody	Premium	Model 4, STD	N/A
4	A	Narrowbody	Economy	Model 1	76.2
5	B	Widebody	Economy	Model 5, IAT	71.1
6	B	Widebody	Economy	Model 5, STD	71.1
7	B	Widebody	Premium	Model 6, IAT	96.5
8	A	Widebody	Economy	Model 2	81.3

Child Restraint System (CRS) Dimensions

CRS dimensions were aggregated from previous publications and reports, each containing full descriptions of how each measurement was collected (Bing et al. 2015, Bing et al. 2018, Bing et al. 2016, Mansfield et al. 2022).

Dimensions from a convenience sample of seven additional CRS were also collected for the current study. For each measurement comparison, there were between 34 and 64 CRS in the sample. Sample sizes vary depending on whether that dimension was collected for each previous study and the type of CRS for which that dimension is applicable. When a CRS dimension appeared to be an outlier from the group, the authors consulted the manufacturer's website to determine if that CRS was still in production. If the CRS model was discontinued, then its data point was removed from the analysis.

Automotive Seat Dimensions

Vehicle seat dimensions were aggregated from previous publications, each containing full descriptions of how each measurement was collected (Bing et al. 2015, Bing et al. 2018, Bing et al. 2016, Mansfield et al. 2022, Mansfield et al. 2024).

For each measurement comparison, there were between 61 and 111 vehicle seats in the sample. Sample sizes for each measurement comparison varied depending on whether that dimension was collected for each previous study.

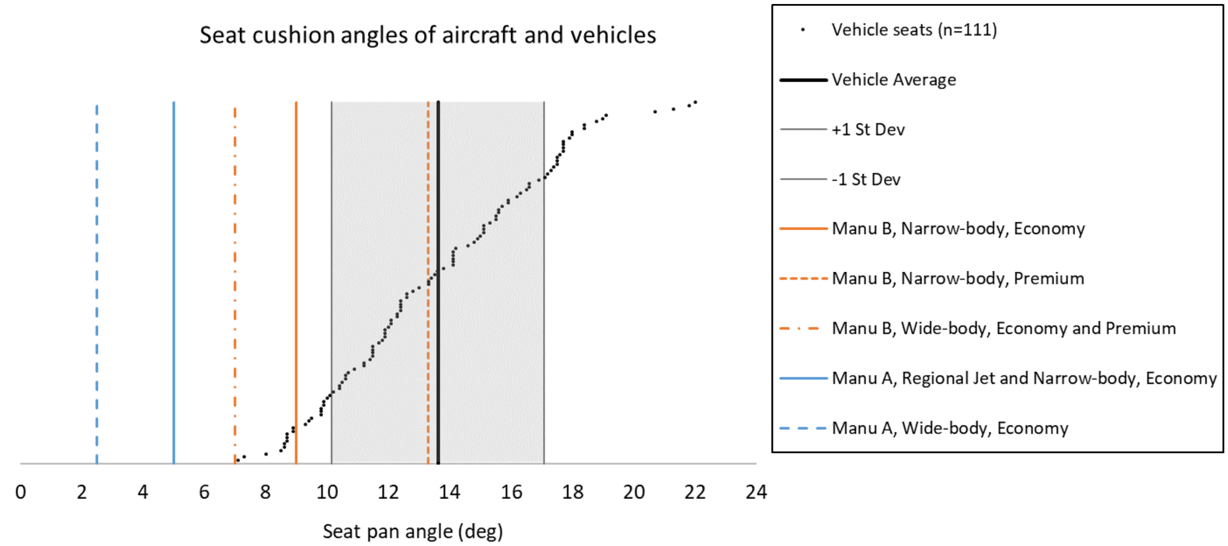
Data Analysis

Plots were constructed to visualize each aircraft seat dimension with respect to the sample of CRS. When applicable, CRS were categorized by orientation (RF or FF) or by type (infant, convertible, 3-in-1, combination). On separate graphs, aircraft seat dimensions were also compared to the relevant corresponding dimensions of vehicle seats. Comparisons to the FMVSS 213 inversion bench and SAE ARP 4466 guidelines are also provided when available.

Results

Seat cushion angles of 111 automotive vehicle seats (rear row, outboard positions only) are plotted in Figure 3 (black dots) with the mean denoted by the solid black line (13.6°) and ± 1 standard deviation (3.5°) shown by the gray lines and gray shading. The aircraft seat cushion angles (measurement #8, Table 1) are shown in blue and orange with specific types denoted in the legend. Seat cushion angles of the aircraft seats tend to be more horizontal than those of automotive seats, except for the premium seats on a narrow-body aircraft from manufacturer B. The seat cushion angle of the FMVSS 213 inversion bench is defined as 10-15° from horizontal. Thus, the FMVSS 213 inversion bench is representative of automotive seats and not commercial aircraft seats.

Figure 3: Seat cushion angles of commercial aircraft seats (blue and orange) compared to vehicle seats (black dots, with gray shading representing ± 1 standard deviation from the mean).



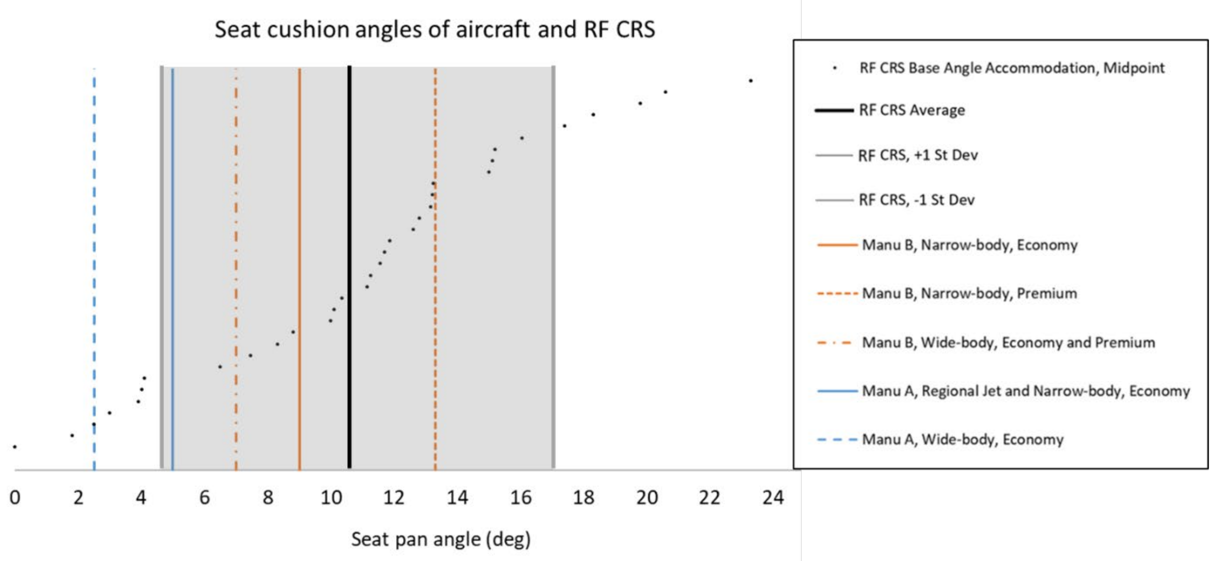
Next, the aircraft seat cushion angles were compared to RF CRS (n=34) to visualize whether the angle of the aircraft seats would position the RF CRS within the manufacturer's recommended securement angle. Each RF CRS typically has a small range of angles (10-15°), which are acceptable for securement and are denoted by a bubble level or "level to ground" line(s) on the product (Figure 4).

Figure 4: Bubble level indicator on a CRS. The manufacturers' instructions indicate that the CRS should be positioned such that the blue indicator is between the two black lines.

The black dots in Figure 5 indicate the midpoint of each RF CRS's acceptable angle range (thus, each CRS can be secured in seats approximately ± 5° degrees or wider ranges if the CRS angle is adjustable). The average ideal cushion angle for the RF CRS examined in this study was 10.6°

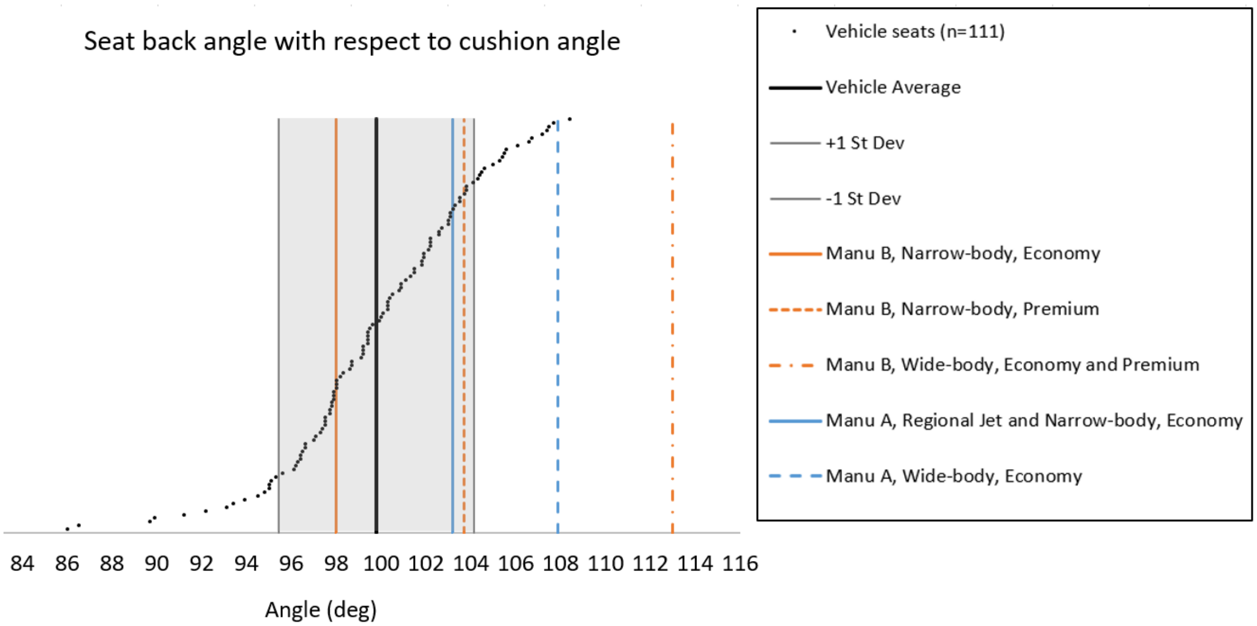
± 6.1°. The aircraft seat cushions accommodate the range of RF CRS angles fairly well. A previous study has indicated that many RF CRS are designed for seat angles that are more horizontal than the average automotive seat (Bing et al. 2015). This occurrence seems to be advantageous in the aircraft setting, where seat cushions are usually more horizontal than vehicle seats. The more horizontal angle can put infants in a more reclined position than most vehicles. A reclined position is recommended for small infants and newborns to maintain good head support and open airways. CRS positions that are too upright can allow young babies' heads to lean forward, blocking their airway and causing positional asphyxiation (Alston et al. 2021). However, the CRS should always be secured and used within the manufacturer's allowable angle range to ensure proper protection during a crash.

Figure 5: Seat cushion angles of commercial aircraft seats (blue and orange) compared to the ideal seat angle for each RF CRS (black dots).



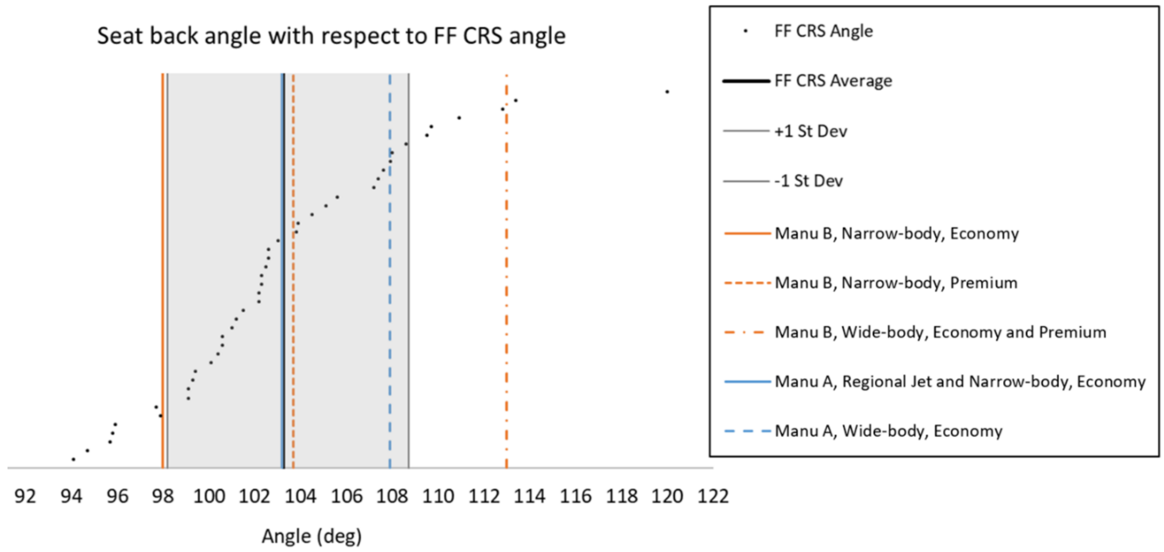
The angle between the seat cushion (measurement #8, Table 1) and seat back (measurement #9, Table 1) was calculated and defined as the "internal angle" of the seat. The internal angles of aircraft seats were compared to those of automotive seats. Figure 6 shows the average measurement from 111 rear row, outboard automotive seats (mean: 99.8° ± 4.4°, black and gray shading) overlaid with the measurements from the aircraft seats. In general, the internal angle of the aircraft seats is similar to that of most automotive seats or slightly more obtuse. The FMVSS 213 inversion bench is defined as 90-95°. Thus, the FMVSS 213 inversion bench is more acute than most commercial aircraft seats and most automotive seats.

Figure 6: Angle between seat cushion and seat back for commercial aircraft seats (blue and orange) compared to automotive seats (black dots, gray shading).



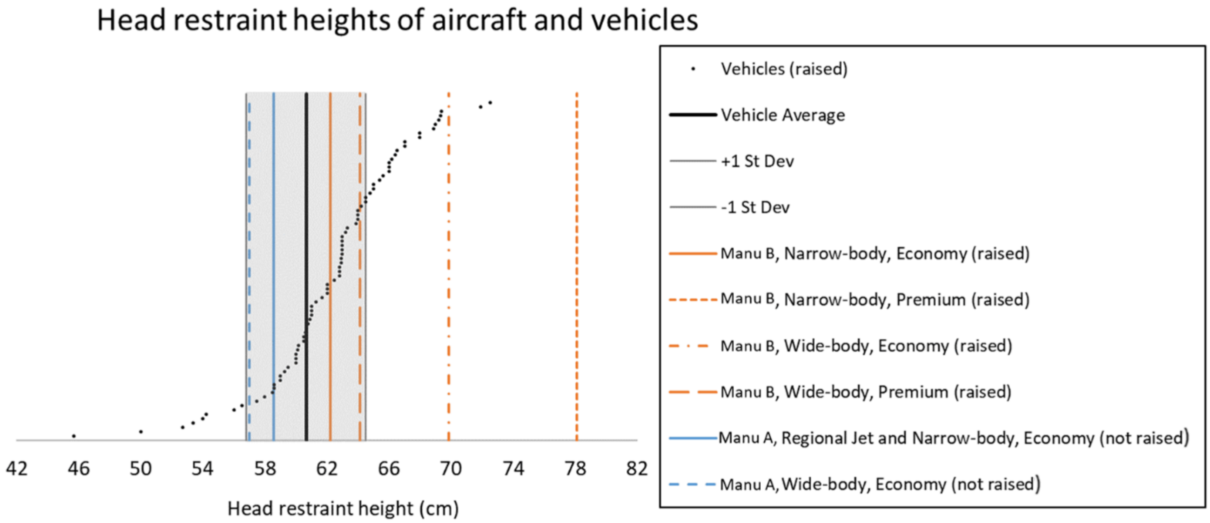
The angle between the base and the back of FF CRS must align relatively well with an aircraft seat's internal angle to achieve a good fit in the seat without major gaps between surfaces. FF CRS angles (n=43) from previous studies were superimposed on the distribution of aircraft seat angles. In general, the internal angles of the aircraft seats fell within ± 1 standard deviation of the mean of the FF CRS sample (mean: 103.2° ± 5.4°), indicating a good fit in this metric (Figure 7).

Figure 7: Angle between seat cushion and seat back for commercial aircraft seats (blue and orange) compared to the back angle of FF CRS (black dots, gray shading).



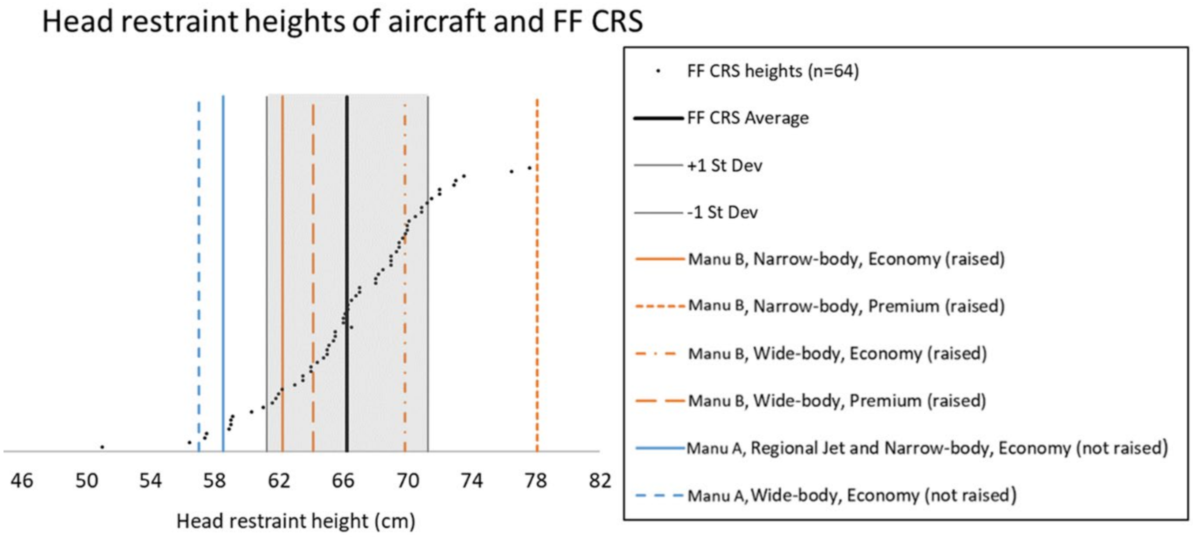
The headrest heights of the aircraft seats (measurement #4, Table 1) were compared to the head restraint heights of automotive seats (Figure 8). The vehicle seat sample contains only those head restraints that either cannot be adjusted or can be adjusted but not removed for CRS securement (n=78, mean: 62.3 ± 4.7 cm). If adjustable, the height reported below reflects the raised height of the automotive head restraint. In general, most aircraft seats have headrest heights that are similar to or higher than those of automotive seats.

Figure 8: Height of head restraint for commercial aircraft seats (blue and orange) compared to automotive seats (black dots, gray shading).



Next, aircraft headrest heights were compared to the height of the back of n=64 FF CRS (mean: 66.3 ± 5.0 cm; Figure 9). This is the height of the product that must fit below the headrest in order to secure without any gaps behind the CRS back. A few of the aircraft seats had headrests that were not high enough to accommodate many of the FF CRS, especially the Manufacturer A seats in blue (Figure 9).

Figure 9: Height of headrest for commercial aircraft seats (blue and orange) compared to the height of FF CRS (black dots, gray shading).



Headrests on aircraft seats are not as thick or pronounced as they are in automotive seats. These smaller aircraft headrests that do not protrude very far in the forward direction may not cause any issues with FF CRS securement, even if the top of the CRS overlaps with the headrest (Figure 10).

Figure 10: Typical economy seat headrests, (A) adjustable headrest and (B) fixed headrest.

The seat cushion lengths (length from bight to front edge of cushion) of the aircraft seats were compared to an automotive seat sample of n=61 rear-row, outboard seats (mean: 47.4 ± 3.0 cm, Figure 11; measurement #6, Table 1). Nearly all of the aircraft seats were shorter than the automotive seats, falling outside of 1 standard deviation from the mean. SAE ARP 4466 recommends that aircraft seats should accommodate a CRS with a length of 410 mm (41.0 cm). While this guideline falls well within the aircraft seat dimensions, it is significantly shorter than any of the automotive seat lengths.

Figure 11: Length of seat cushion for aircraft seats (blue and orange) compared to vehicle seats (black dots, gray shading) and SAE 4466 recommendation (purple line).

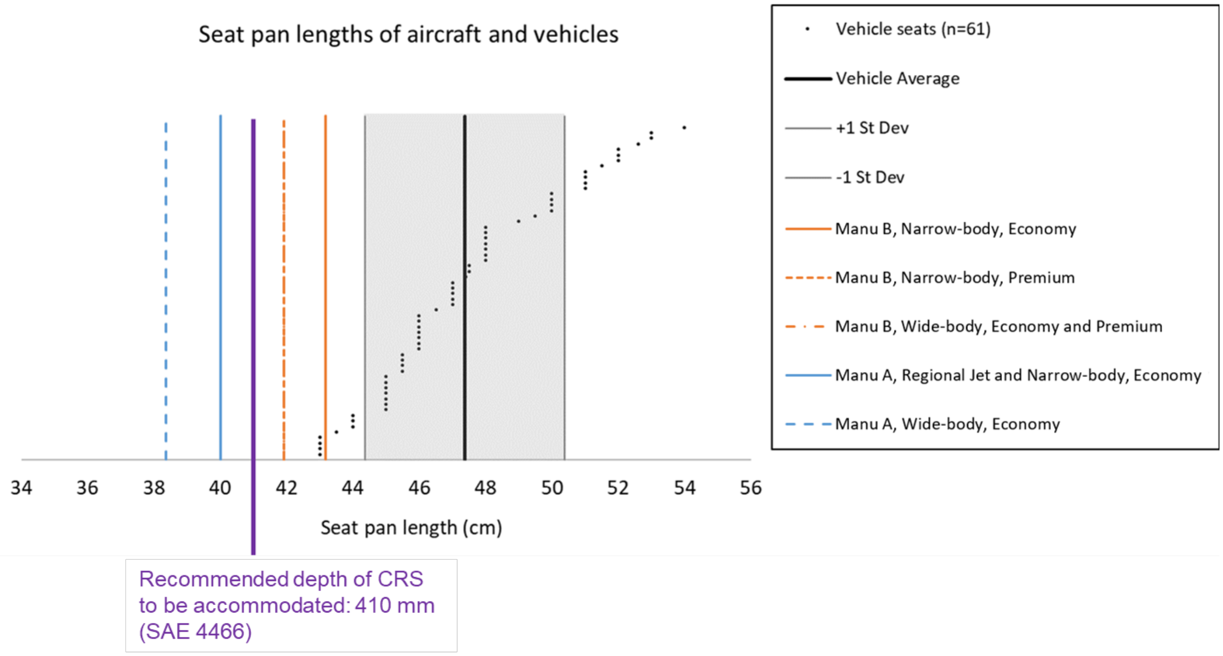
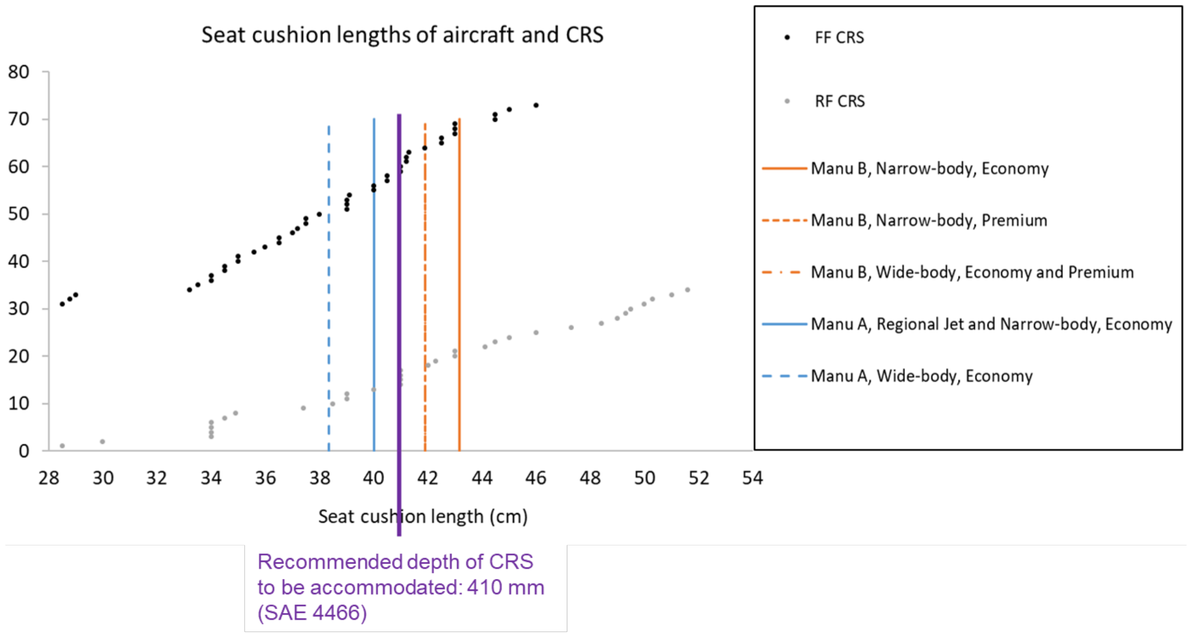


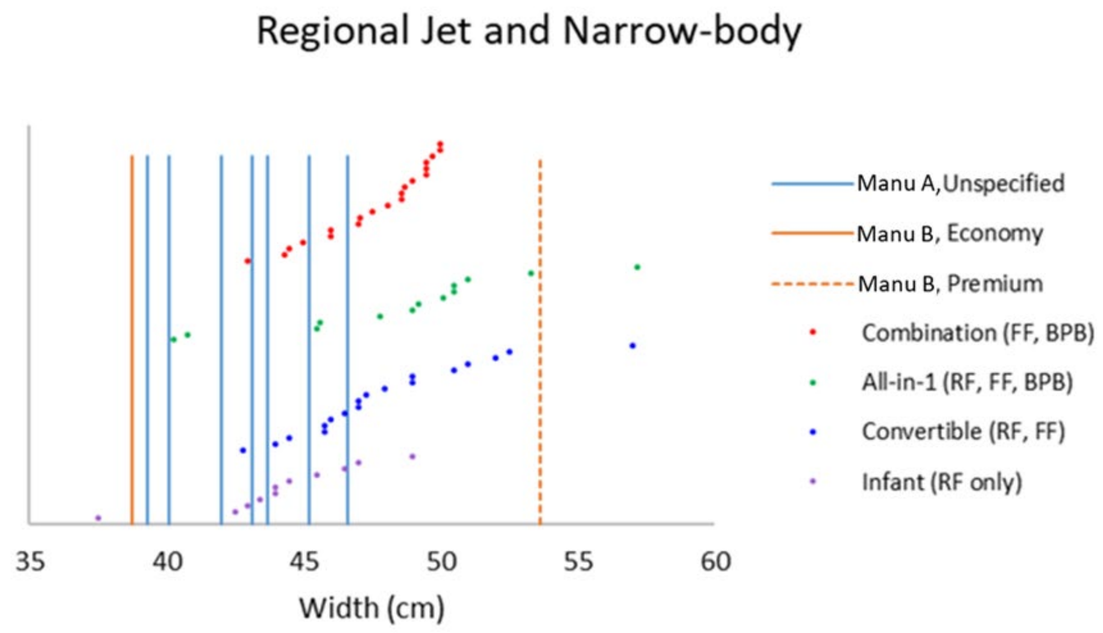
Figure 12 shows base lengths from FF CRS (n=43, black dots) and RF CRS (n=34, gray dots). The comparison against aircraft seat lengths (blue and orange lines) indicates that the aircraft seats might be too short to accommodate some of the CRS on the market, especially RF CRS, because their bases tend to be longer than FF CRS (means: 41.7 cm ± 6.3 cm vs. 38.4 cm ± 4.3 cm, respectively). The SAE ARP 4466 recommendation again matches the range of aircraft seats well but might be too short for some of the available FF CRS and many of the RF CRS.

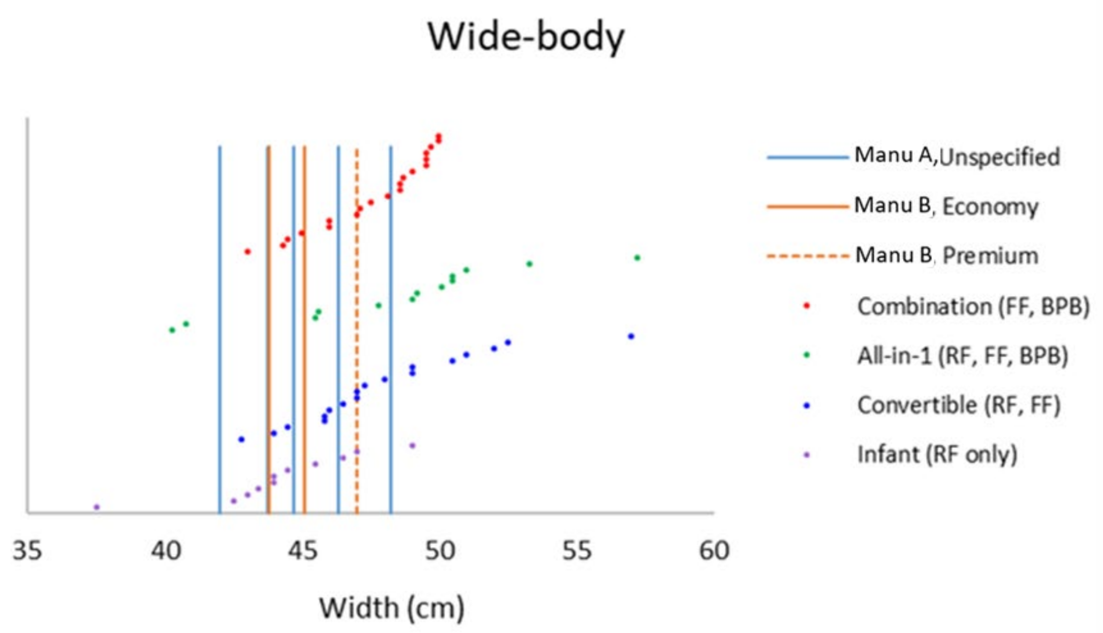
Figure 12: Length of seat cushion for commercial aircraft seats (blue and orange) compared to FF CRS (black dots) and RF CRS (gray dots), and SAE 4466 recommendation (purple line).



The width between armrests of each aircraft seat was compared to the width of the widest point of n=56 CRS near the base/armrest area (mean: 47.7 cm ± 3.6 cm across all types, Figure 13; measurement #1, Table 1). CRS are denoted by type: n=10 infant, n=16 convertible, n=12 all-in-one, n=18 combination. Aircraft seats are shown on separate graphs for narrow-body and wide-body configurations. Wide-body configurations are able to better accommodate CRS in this metric. However, many of the wider CRS cannot be accommodated by most of the aircraft seats included in this study with the armrests down. It is recommended to secure a CRS on an aircraft in the window seat that may provide some additional width, or if the caregiver is seated next to the CRS, they can raise the armrest in between the seats to provide additional width. With the CRS installed at the window, it does not interfere with available space if an evacuation is needed.

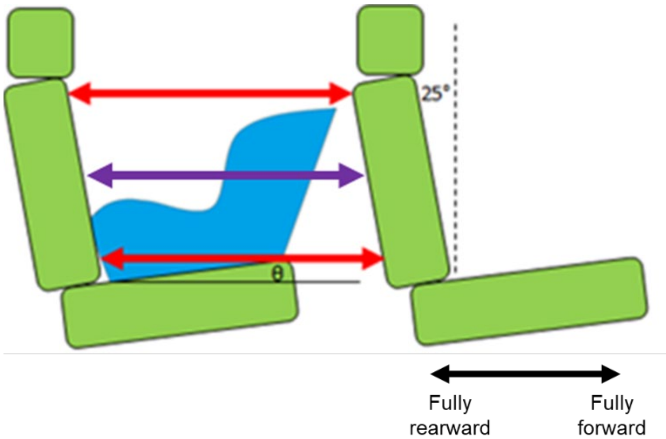
Figure 13: Width between armrests for commercial aircraft seats (blue and orange) compared to the widths of CRS at the widest point near the base/armrests. CRS are subdivided into four different types.





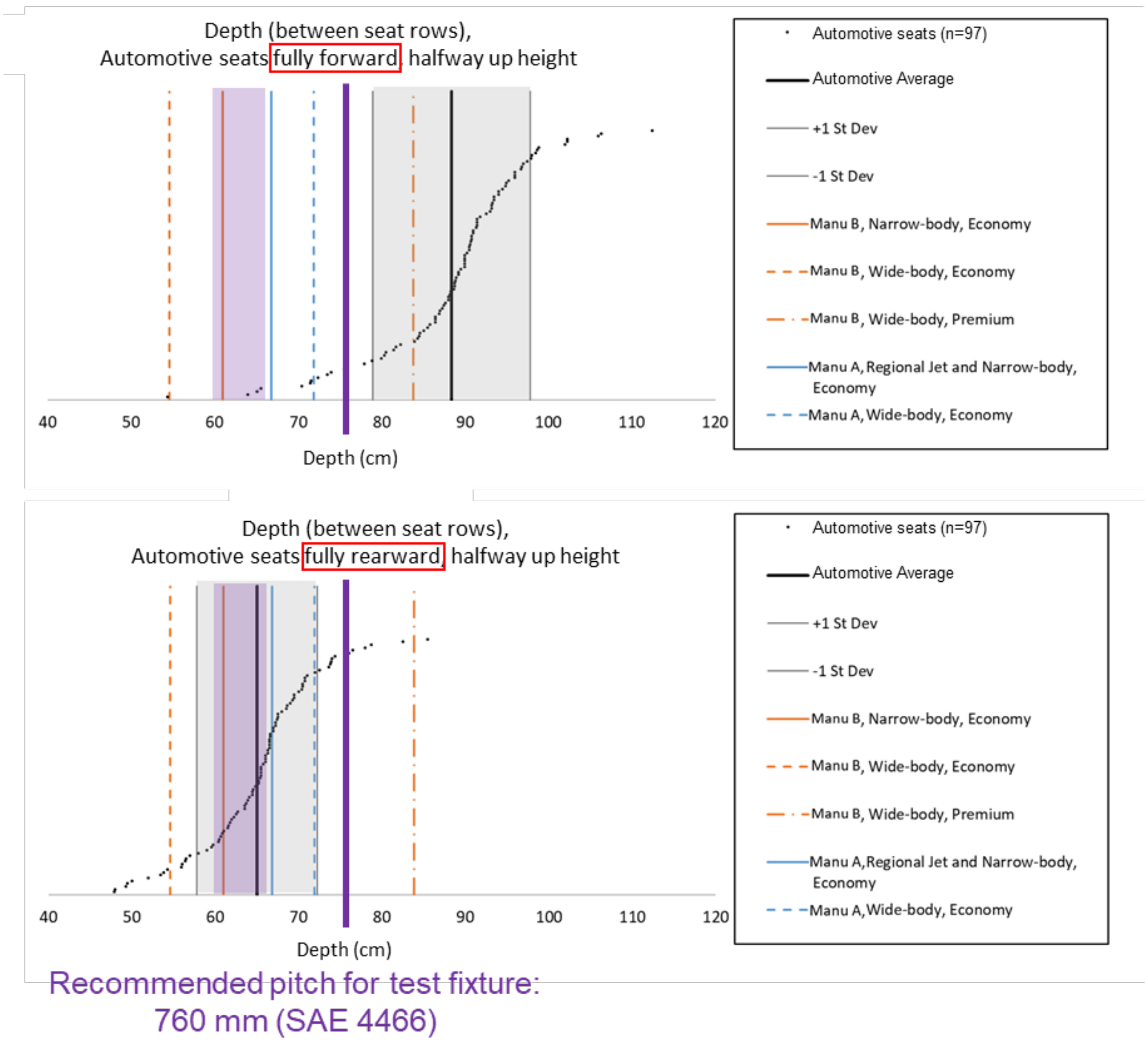
The aircraft seat depth is reported from measurement 7b/7c (Table 1), which is approximately midway up the seat back. The available space between aircraft seats in the fore/aft direction (seat depth) is compared to the corresponding seat depth in automotive seats (n=97). Front row automotive seats can usually be adjusted in the fore/aft direction on their slider track, which drastically changes the depth between seats (Figure 14).

Figure 14: Seat depth was measured in automotive seats with the front row slider track fully forward and fully rearward. Seat depth was measured at a low height and a high height (red arrows). The mid-level height was calculated and is reported here (purple arrow).



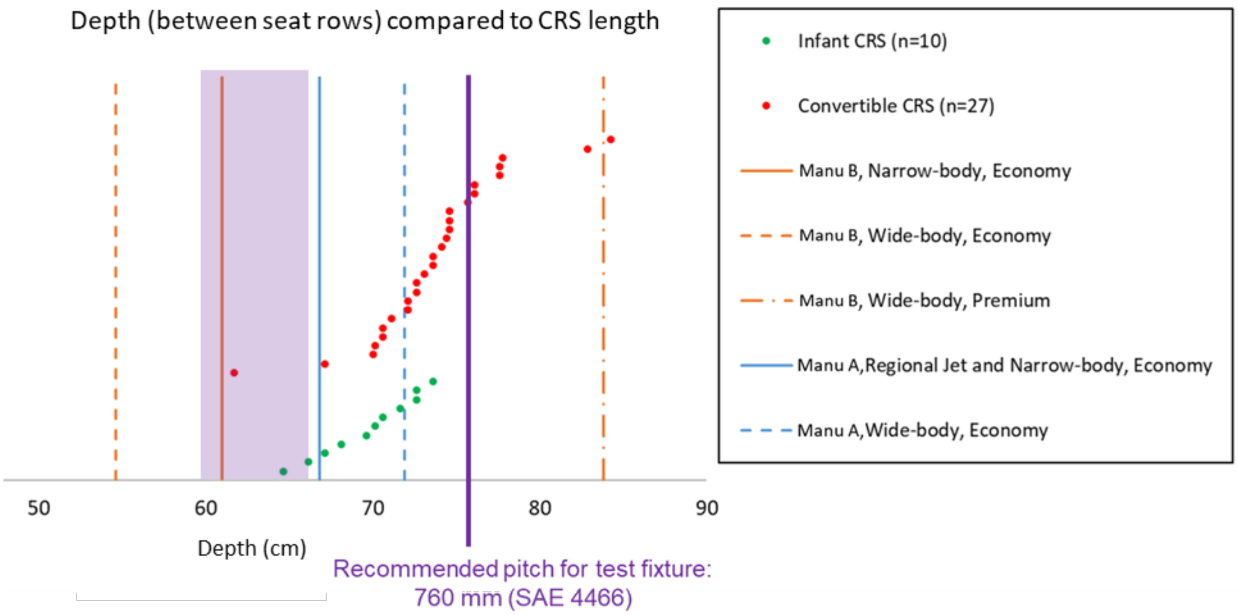
Automotive seat data are presented with the slider track fully forward (mean: 88.4 cm ± 9.5 cm; Figure 15 top) and fully rearward (mean: 65.0 cm ± 7.2 cm; Figure 15 bottom). The aircraft seat depth (superimposed on both figures) aligns more closely with the slider track in the rearward configuration. The SAE ARP 4466 recommended pitch of 760 mm (76.0 cm) is greater than most of the seat depths measured from aircraft environments in this study. However, since there is no information presented in ARP 4466 on the actual design of the seat, the seat depth for that pitch cannot be calculated. For example, Manufacturer B has two seats with an installation pitch of 71.1 cm, but the mid-point measurement of seat depth (measurement 7b) is 61.0 cm for one seat and 54.6 cm for another seat. This highlights the difference between pitch and depth. The SAE ARP 4466 pitch guideline (760 mm, or 76.0 cm) may represent an actual seat depth (fore/aft space between seats) of approximately 60.0-66.0 cm. This distance falls near the range similar to the automotive seat fully-rearward track position.

Figure 15: Seat depth between seats for commercial aircraft seats (blue and orange) compared to automotive seats (black dots, gray shading) and SAE 4466 pitch recommendation (purple line) with estimated depth range (purple shading). The top plot considers the automotive seats in their fully forward slider track position, and the bottom plot considers automotive seats in their fully rearward slider track position.



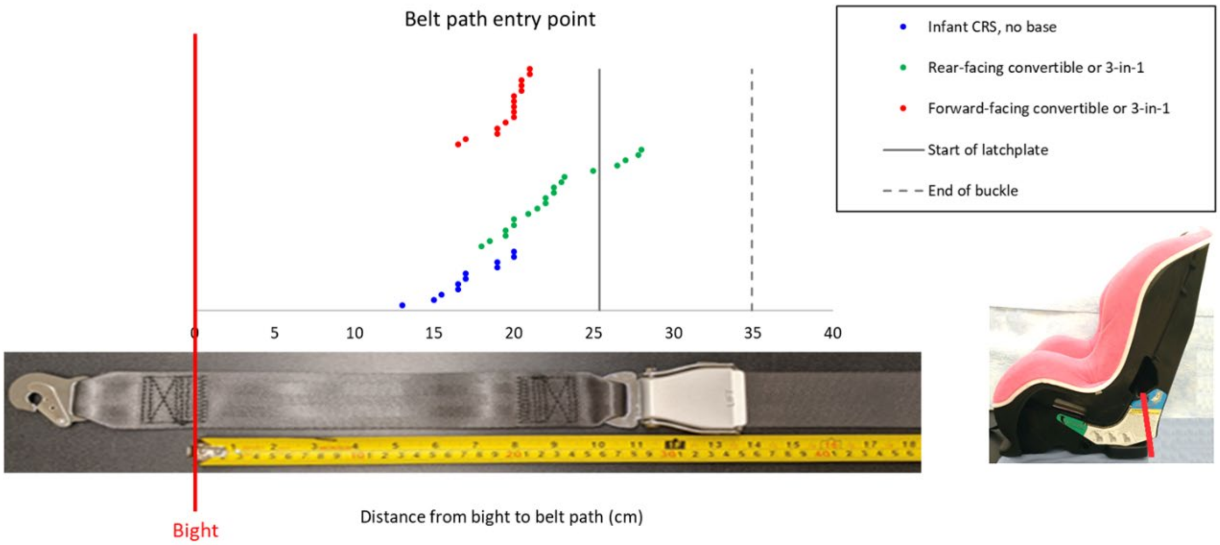
Comparing aircraft seat depth (n=38) to RF CRS lengths indicates that most aircraft seats cannot accommodate convertible CRS in RF mode (mean: 73.8 cm ± 4.4 cm; Figure 16, red dots). The exception is the wide-body premium seat from manufacturer B, which is expected since it had an installation seat pitch of 96.5 cm that was 15-25 cm greater than the other installations reported. Infant seats can be more comfortably accommodated in some aircraft seats (mean: 69.7 cm ± 2.9 cm; Figure 16, green dots). The SAE ARP 4466 pitch guideline (760 mm, or 76.0 cm) may represent an actual seat depth (fore/aft space between seats) of approximately 60.0-66.0 cm. According to this estimate, only a few of the RF infant CRS or RF convertible CRS would be accommodated.

Figure 16: Depth between seats for commercial aircraft seats (blue and orange) compared to RF infant CRS (green dots) and RF convertible CRS (red dots), and SAE 4466 pitch recommendation (purple line) with estimated depth range (purple shading).



Aircraft lap belts include buckle hardware in a different location compared to most automotive seats. While automotive seat buckle hardware is typically anchored to one side near the seat bight, aircraft buckle hardware is oriented about 25 cm (10 inches) away from the seat bight (measurements 11a and 11b, Table 1). The hardware is approximately 10 cm long. If the buckle itself falls over the top of a sharp curve in the CRS belt path, it can be difficult to tighten the seat belt to create a snug fit. In this case, the fixed portion of the seat belt may have to be twisted to shorten it and have the buckle fall outside the belt path. Additionally, if the aircraft seat belt buckle is routed into the belt path, it can be oriented directly behind the child occupant’s back and create discomfort during sitting (because many CRS only have a thin piece of foam or fabric between the seat belt path and the child). The comparison of the aircraft seat belt and the seat belt entry points of n=57 CRS (measured from the bight area for both) indicates that the aircraft seat belt buckle will route into the belt path for most CRS (mean across all types: 25.0 cm ± 2.4 cm; Figure 17). In other words, the height of the seat belt entry point of the CRS is less than 25 cm, so the buckle itself will fall somewhere within the seat belt path, and not on the outside of the CRS shell as in most automobiles that have relatively short buckle stalks.

Figure 17: Length of seat belt compared to height of seat belt path entry point on CRS (traced in red on the CRS image). CRS are plotted by type and orientation.



Discussion and Conclusions

The main goal of this study was to produce data that aircraft manufacturers and CRS manufacturers could use to understand how their products work together. The data presented here shows the ranges of metrics of each product.

Corresponding dimensions were compared across data sets to summarize the main predicted points of compatibility issues. The main areas of consideration between CRS and aircraft seats are:

- Depth (fore/aft clearance): The depth in most aircraft seats is similar to that of automotive seats, with the front row slider track in its fully rearward position. This might create challenges for convertible RF CRS, although they may accommodate most RF infant seats.
- Seat cushion length: Aircraft seat cushions are shorter than most automotive seat cushions.
- Width between armrests: Aircraft seats with armrests introduce an additional width compatibility consideration, which is not typically an issue in most automotive seats.
- Seat cushion angle: Aircraft seat cushions are more horizontal than most automotive seats. This could place an infant in a more reclined position than usual when a RF CRS is secured in an aircraft seat. This could have advantages in terms of keeping small infants reclined enough to keep their heads upright and airway open. However, the angle should always be checked against the CRS manufacturer’s recommended range for proper functioning of the CRS in a crash.

The study includes several limitations. Unfortunately, due to security restrictions and the COVID-19 pandemic, researchers were unable to gain access to actual aircraft seats to complete any physical securements at the time of this study. Validation of the fit metrics examined in this study would have been a valuable addition to this study to ensure realistic conclusions about potential problem areas. Aircraft measurements from eight seats were obtained, representing two of the major seat manufacturers. A larger variety of seats and manufacturers would have been beneficial to the study. The comparison measurements from vehicle seats and CRS were combined from several previous studies. Some of the vehicles and CRS are older models, which may not be popular in the field currently.

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Appendix A: Data Management Plan

Dataset and Contact Information

Title: Analysis of Child Restraint System (CRS) Compatibility with Aircraft Seats
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https://ibrc.osu.edu/
Funder: Center for Child Injury Prevention Studies (CChIPS)
Grant/Contract(s): N/A
Persistent link: https://doi.org/10.21949/1529728
Recommended Citation: U.S. Department of Transportation, Federal Aviation Administration. (2025). Analysis of Child Restraint System (CRS) Compatibility with Aircraft Seats [datasets]. https://doi.org/10.21949/1529728

Project abstract

The Federal Aviation Administration (FAA) encourages the use of aircraft-approved CRS. However, as established through prior CChIPS research, caregivers often encounter challenges installing CRS on aircraft seats. The broad objective of this study was to quantify the specific compatibility concerns between CRS and aircraft seats to ultimately facilitate higher rates of CRS use on aircraft.

Project start date: October 2023
Project end date: September 2024

Data Description

This dataset contains measurements of child restraint systems and aircraft seats. Physical measurements created this data via standard hand tools. The measurements were collected from 2013 to 2023. The existing data used for this project is referenced in the accompanying paper and is included in this data set.

It is anticipated that aircraft seat manufacturers and consumers will benefit from access to this data to minimize the risk of difficulty when installing a CRS into an aircraft seat. This dataset will also provide a public record to support any potential rulemaking.

Roles & Responsibilities

The Injury Biomechanics Research Center at The Ohio State University (see *Contact Information*) was responsible for generating the data and managing the data initially. The FAA Aeromedical Research Division curated the data for public dissemination. This division is responsible for managing the internal project management processes to ensure adherence to the published data management plan (DMP). This process requires management review and sign-off at project start and close-out.

The dataset will be archived in the National Transportation Library Repository and Open Science Access Portal (ROSA P).

Standards Used

The data files collected here are saved in the ubiquitous and common .csv file format. Documentation will include this data management plan and a readme file. The readme file will include the variable definitions and data dictionary.

Necessary software tools: The file formats found in the zip files include: .txt files, which can be opened using any text editor; and .csv files, which can be opened with Microsoft Excel, and other free available software, such as OpenRefine.

Access Policies

These data files are in the public domain and can be shared without restriction. The data files contain no sensitive information.

Sensitive Data Policies

The data files contain no sensitive information.

Sharing Policies

These data are managed by the National Highway Traffic Safety Administration. The data are in the public domain and may be reused without restriction. Citation of the data is appreciated. Please use the following recommended citation: U.S. Department of Transportation, Federal Aviation Administration. (2025). Analysis of Child Restraint System (CRS) Compatibility with Aircraft Seats [datasets]. https://doi.org/10.21949/1529728

Archiving and Preservation Plans

The dataset will be archived in the National Transportation Library Repository and Open Science Access Portal (ROSA P). Prior to archiving, the data are stored on the secured FAA networks and drives, which are backed up nightly. The US DOT systems are secured from outside users and backed up daily. ROSA P meets all the criteria outlined on the "Guidelines for Evaluating Repositories for Conformance with the DOT Public Access Plan" page: https://doi.org/10.21949/1520563.

The dataset will be retained in perpetuity.

FAA staff will mint persistent Digital Object Identifiers (DOIs) for each dataset. These DOIs will be associated with dataset documentation as soon as they become available for use.

The DOIs associated with this dataset include: https://doi.org/10.21949/1529728

Applicable laws and policies

This data management plan was created to meet the requirements enumerated in the U.S. Department of Transportation's 'Plan to Increase Public Access to the Results of Federally-Funded Scientific Research' Version 1.1 https://doi.org/10.21949/1520559 and guidelines suggested by the DOT Public Access website https://doi.org/10.21949/1503647, in effect and current as of June 3, 2025.