# USABILITY STUDY OF CHILD RESTRAINT SYSTEM (CRS) FOR INFANTS IN THE AIRCRAFT

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**ABSTRACT**

*It is not an exaggeration to say that safety is a must while travelling either on land, sea or even air. Especially for small travellers that would not be able to take care of themselves alone when unexpected situations happen during the journey. A seatbelt is so far very essential for everyone to stay put on seat, but it is widely designed as built-in which specifically for normal adult size and body structure, while for children they need a special design safety device for travelling. The well designed device for their protection, especially during a crash is known as Child Restraint System (CRS) that was first introduced by the National Transportation Safety Board (NTSB) and issued to the Federal Aviation Administration (FAA) about the CRS for aircraft as air transportation. This paper reviews features of CRS, types of CRS, guidelines and installations of CRS for infants in the commercial aircraft.*

***Keywords: Child Restraint System (CRS), Usability, Installation, Safety***

## I. INTRODUCTION

Since 1993, National Transportation Safety Board (NSTB) had reviewed the safety statistics on aircraft operations and had calculated aircraft accident rate [1].As a result of almost 30 years studying about the aircraft accidents, the Safety Board has issued eight recommendations to the Federal Aviation Administration (FAA) and one of the recommendations, concerns about children aircraft occupants which the infants or children under age 2 must be restrained in their own seats by using the government approved child restraint system (CRS). In agreement to the recommendation, the FAA was emphasized that, during turbulence or an emergency, the infant should be in the safest place that is their CRS rather than to be in their parent's laps because the parents are unable to securely hold on the lap-held child during turbulence or emergency. According to the FAA, turbulence can be caused by the atmospheric pressure, jet streams, thunderstorms, unexpected weather fronts and also caused by the air around the mountains [2].

Civil Aviation Safety Authority (CASA) had prepared a Civil Aviation Advisory Publication (CAAP) as to cater the relevance and interpretations towards regulations 235 and 251 of the *Civil Aviation Regulations 1998 (CAR)* and specifically to paragraph 13 of Civil Aviation Orders (CAO) 20.16.3 'Air Service Operations – Carriage of Persons'. CRS is a well-designed device specialized to protect small aircraft occupants whose body structures and figures are still developing where their sizes and ages take into accounts. Some studies had reviewed the principles and mechanisms of CRS as well as the utilization of CRS.

## II. THE FEATURES OF CRS

A CRS is a government approved device for use in motor vehicles and aircraft with hard-backed design of child safety seat [2]. Child Aviation Restraint System (CARES) is an FAA approved device for special safety seat use in aircraft due to not all automotive CRS can be used in aircraft because of their unrecognized designs and may cause harm to the users. CARES child safety device is approved in accordance with 14 CFR 21.8(d)"Approved for Aircraft use Only" [3]. The approval is clarified due to fulfillment of the specifications of the CRS from the components to their mechanisms and functions.

**Seatbelt.** A seatbelt is former standard equipment in most of the vehicles. It is a combination of lap and shoulder belts. In vehicles, including aircraft, the seatbelts are designed normally for adult size, which is not relevant for children with small body structures and stability. Seatbelts may not give harm, even for kids and should be innovated to complement the structures of CRS [4, 5]. A statistical analysis by Canadian researchers stated that seatbelts can reduce fatalities and severe injuries for small occupants age 4 through 14 approximately by 40% [6]. There is a standard for child size and measurements, including the weight and height of the child. A study by Klinich *et al*., found that a child needs to sit straight to have a sitting height of 74cm for effectively use the belts and in order to get the best fit, the kid is required to sit in a forward facing manner as it pelvis as vertically far back into the seat [7].

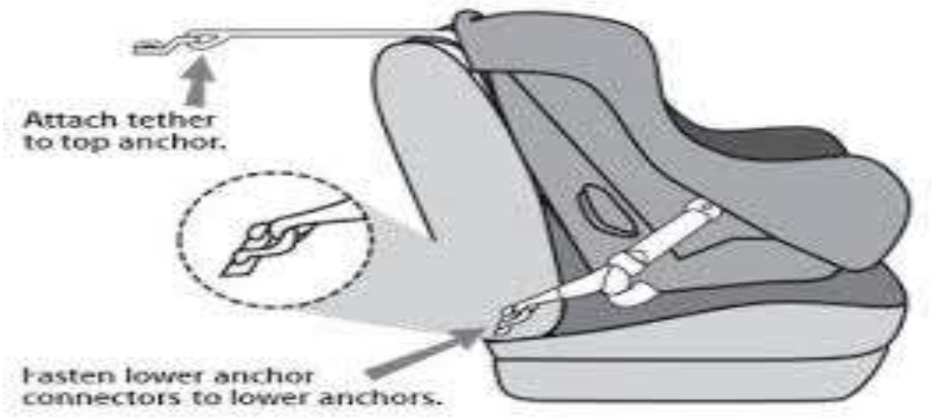


**Fig. 1: Position Of Anchor And Top Tether [12]**

**Top tether.** Early 1980s, the top attachment strap for safety of the passenger head was then concerned. Top tethers keep the child's head safe during the crash, but people at that time refused to install the top tethers in their vehicles [8]. Top tethers are very easy to install as compared to seatbelts. In the United States, most of the vehicles are recommended to install the restraint system with standard or advanced tethers as the regulations made need the manufacturer to install user-ready anchor. Besides that, the installation approach is supported by having older vehicles to also install the system of restraint for safety prospective [9].

**Anchor.** ISOFIX is the first concept introduced in 1991 to propose standard rigid interface hardware for vehicles and on child restraints [10]. This approach was to reduce the degree of error while doing the child restraint system installation as well as to improve crash performance of the vehicles. In the development of child restraint system, the use of additional anchors was introduced as the two lower anchors at the seat bight were not enough to isolate the restraint system from the seat cushion [11]. There are two types of anchorage; the flexible anchorage and rigid anchorage. The figure 2 below shows the anchorages and attachments of the child restraint system.

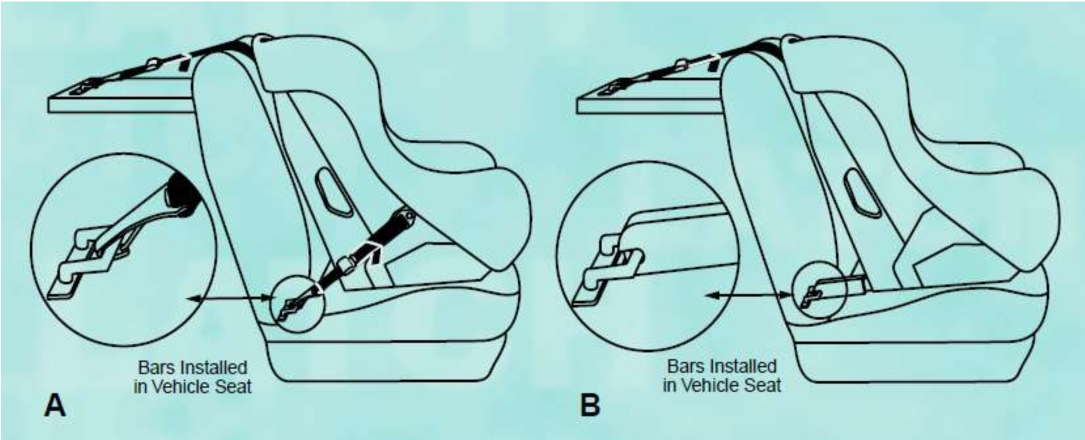


**Fig. 2: (A) Flexible Anchor And (B) Static Anchor [12]**

**Harness.** The harness was firstly design in military with a pattern of 5-point harness which strap over shoulder, pelvis and legs by each point is buckled firmly for safety purposes. The harness gives more lateral support for the child by applying the concept of lap-held positioning to ensure comfort for the kids as they tend to squirm around during the journey. This will definitely reduce the risk of falling during take-off or landing. The use of firm padding could keep the children from slouching [13] as it will compress during impact and serve as energy absorbency to protect the child's body [12]. Currently, there are few designs of harness available besides traditional 5-point harness, such as tray shield and T-shield. Tray shield is designed to have shoulder and crotch straps while the T - shield is more likely to come with shoulder straps as shown in figure 3.

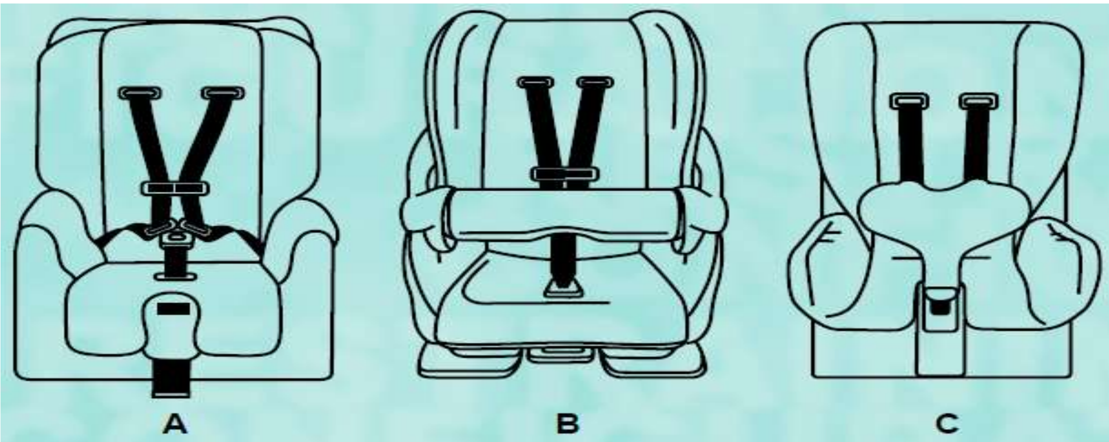


**Fig. 3: Types of harness designations of CRS: (A) 5-point harness, (B) tray shield and (C) T-shield [12]**

## III. TYPES OF CHILD RESTRAINT SYSTEM

**Built-in airplane seatbelts.** A built-in seatbelt also known as an integrated seatbelt is an approach studied in Sweden and currently in North America [14, 15]. This built-in system is to directly link the child to the seat of the vehicle. The installation is very perfect with correct parameters of buckle size, belt anchor location, type of retractor and latch plate [16]. Unfortunately, this kind of restraint has its disadvantages. Recent analysis has stated that children in seat belts are 3.5 times more likely to suffer serious injury, especially to the head as compared to the restrained children [17]. Since the system is built in and integrated, it is unable to be uninstalled or reinstalled. The system is unable to be removed when it is no longer needed. In marketing view, this system is not marketable and been analyzed to reduce in the future, even the National Transportation Safety Board (NTSB) suggested the vehicle producers to offer this system in their vehicles.

**Rear-Facing Child Restraint System (RFCRS).** RFCRS has the ability to reduce about 70% the risk of deaths and serious injury if the system is properly installed and secured [18] as to compare with the lap held practise which approximately reduce the risks by only 50% [19, 20, 21]. The design with carrying handles and have detachable base for repeating installation. This device has a very close relationship with a factor of weight. There are certain weights concerned to use this type or restraint as well as for installation. This type of restraint is used to minimize the impact or injury to the upper structures especially necks and heads. According to Melvin *et al*., [22] a proper installed RFCRS is said to be super effective during crash with 96% of injury-reduction effectiveness [23].

**Forward-Facing Child Restraint System (FFCRS).** Forward-facing orientation is a common positioning of children, which most parents believe that this position is more likely to be safest position. The installation of FFCR must be very proper since the safety degree and stability of this device totally depend on the anchorages and attachments credibility. There is a study of Bioengineering that proved this understanding is wrong because it found the risk of child's cervical spine can be pulled apart is very high because the shoulders are held back during the crash [24]. According to CAAP (2013) [25], under 6 months, infants are restricted to be seated in FFCRS but need to be lied down in RFCRS due to their small body sizes unlike the over 6 months infants whose can sit upright in FFCRS provided with the installation of shields, harness and tethers. Not only the features and designs, but the orientations of devices also need to be approved under no circumstances.

**CARES child safety device.** This device is perfectly designed specialized for the aircraft with certain optimization of common devices available for all types of vehicles. The interfaces are complementary to the structures and materials of aircraft seat types and the only device that has an approval from the FAA. The FAA is one of the organizations that urges whole world parents to use CARES for their children when opt to travel by planes. According to CAAP [25], there is a list of CRS designs which meet the standard of approval in accordance to specifications and can be safely used in aircraft. The designs are listed as follows:

1. CRS, which has FAA Technical Standards Order (TSO) TSO-C100, TSO-C100a, TSO-C100b, or TSO-C100c certification.
2. Type 2040-1 Carechair, manufactured by Aviation Furnishings International Limited in acceptance by the Civil Aviation Authority (UK).
3. Skykids® Child Seat, manufactured by Innovint Aircraft Interior GmbH in acceptance by Luftfahrt-Bundesamt (Aviation Authority of Germany).
4. CRS-2000 PlaneSeat™, manufactured by Amsafe, certified by FAA under Federal Aviation Regulations 21.305(d).
5. Any CRS with integrated and certified as a part of aviation based seat.

## IV. INSTALLATION OF CRS

Restraint system installation has its own challenges and difficulties. In agreement to the purpose of installing this system, the safety is obviously concerned hence the installation must be made perfect with zero error. Once the system is tested and approved by the established accreditation and specifications, then only the system can be widely used by the community. Here comes the matter when a very basic device of restraint system is seat belt that originally constructed in a vehicle for adult-size passengers. The design is not compatible with the body structures of infants or children. Therefore, special designs and innovations for the restraint system have been created to improve the level of transportation safety standard. There are a few improvements in restraint system specifically for child occupants such as built in child restraint, top tethers, and anchorages. In addition, there is a standard provided by FAA to assist technicians or even parents in installing a CRS on airplane by choosing a CRS based on a child's weight. The FAA also urges parents to correctly decide the best choice of CRS approved by that board during all phases of flights. The right manuals and procedures of installation must be perfectly followed by the installers who might be the plane crews, technicians or parents for self-installed devices. Table 1 shows a CRS type selection based on weight as a guideline for best safety choice.

| Child weight | Types of CRS |
|---|---|
| Less than 20 pounds | Rear-Facing CRS (RFCRS) |
| 20 pounds to 40 pounds | Forward-Facing CRS (FFCRS) |
| 22 pounds to 44 pounds | CARES child safety device |
| More than 40 pounds | Built-in airplane seatbelt |

**Table 1: CRS Selection Based On Weight Range Of A Child [2]**

## V. CONCLUSION

Child Restraint System is proven to have significant safety value towards the child occupants of all types of vehicles, especially for aircraft whenever it is experiencing turbulence or crash. The degree of protection is non questionable as the CRS is well innovated with the functionalities of each of the features that meet the standard of performance and accreditation. Every single part of CRS is well studied and engineered to focus perfectly for the crash and impact encounters in order to save lives of the occupants thus reducing the death or injury statistics. All parts integrated with each other and work accordingly, such as seatbelt and tether, harness and shield as well as the attachment system of anchor.

The types of CRS also distinguished according to the size, height and weight of the occupants to ensure safety, stability, effectiveness and also comforts. Each design gives specificity to encourage good safety practices during travelling. Normally, forward-facing CRS is used with a belief of the safest position for children, luckily this study has highlighted the best orientation and structures that suit the infants and the importance of to correctly select the appropriate CRS type according to physical factors of the this group of travelers. Besides features, structures and types of CRS, the installation technique of CRS also play an important role in making sure that the CRS is 100% secured and well installed, thus increase the level of safety for children to sit on an airplane during travelling.

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