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Weight Engineering

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In This Issue

WEIGHT MANAGEMENT FOR AIRCRAFT PASSENGER SEATS

by
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Abstract

In this paper, the company RECARO Aircraft Seating, and the different seat types are presented in order to show the scope of work of the weight department starting from lightweight economy class seats without any IFE up to full-flat electrical business class seats.

The paper delivers insight into the work of an weight engineer in aircraft seat development and production. It shows the different tasks during the project phases from the project start to the final seat and also the daily work to support the project engineers and sales management.

The tools and methods of weight estimation, calculation, and tracking are described. Also described are the collaboration with the production line, the sales department, and the suppliers in order to get actual weights to improve the maturity of the weight data.

The connection to other departments like stress calculation, crash simulation, and testing is also shown. The paper gives an outlook on future challenges to keep the seat weight low, simultaneously improving the comfort and implementing extensive entertainment systems.

1 . The Product Range of RECARO Aircraft Seating

The company RECARO started in 1906 with the production of bodyworks. In 1957, they began building seats for the automobile industry. The year 1969 was the starting point for producing aircraft passenger seats.

Today, Recaro Aircraft Seating (RAS) has over 1,300 employees worldwide and is producing in Schwtibisch Hall, Germany; Fort Worth, USA; Swiebodzin, Poland; Cape Town, South Africa; and soon in China.

The product range includes a variety of seat types, starting from lightweight economy class seats without any IFE up to full-flat electrical business class seats (see Figure 1).

2. The Importance of Weight for Aircraft Design

The aircraft empty weight is a significant influence factor on the fuel consumption and therewith on the economy and environmental impact of an airplane.

Figure 1. SL3510 E/C 9.2 kg (20.3 lbs) per pax

CL6510 B/C 66.7 kg (147 lbs) per pax

A reduction of the aircraft empty weight by 1 kg (2.2 *lbs)* decreases the fuel consumption of an Airbus A330-200 by approx. 1000 kg (2204 *lbs)* per year.

Relating to a number of 480 pax on an A380, a reduction of the seat weight of 0.1 kg (0.2 *lbs)* per pax will result in a fuel saving of approx. 48 t (106000 *lbs)* per year.

For this reason, the weight of the cabin equipment is the focus of aircraft manufacturers on one hand and airlines on the other hand. It is always a compromise between the best comfort and the lowest weight.

From the passenger's point of view, the ergonomics and the seat pitch are more important — the aircraft manufacturer looks for a light seat in order to reduce the loads applied to the seat tracks. This allows the manufacturer to reduce the strength of the cabin floor and the adjacent aircraft structure. This has the effect of lighter structure, along with benefits in performance and fuel consumption.

The airline is also pleased with lighter aircraft, but the possibility to fit more (light) seats into the same cabin in order to reach a higher revenue with each flight is even more important for them.

So the seat designer is confronted with two opposing requirements: produce a seat that is lighter than anything on the market, but one that also contains all the newest features in In-Flight Entertainment (IFE) and comfort – for the lowest price.

To meet all these requirements and to always have a reliable weight status is the main task for weight engineers in the seat industry.

3. The Scope of Weight Management

The weight department is connected to many other departments inside and outside its own company (App.1). It initiates weight and CG checks for parts, assemblies, and complete seats. Mostly these values were prepared by the designers with the help of CAD-Programs. Complete assemblies were either weighed by the supplier, or by the stock receiving when delivered. A process has been established between the weight department and the storage facility, that each part taken out of the inventory must be weighed if no weight data is available in the database (SAP).

Complete seats for weight and CG checks are measured on a CG Scale. This task will be described later on.

The seat itself is split into modules and each seat model has its own platform. The weight department is responsible for giving target and layout weights for each module, so that a seat target weight given to a customer is broken down to each module. Each module engineer has a limit as guideline for the development of his part, e.g., armrest, backrest, or seat base.

The sales department delivers any customer request to the weight group. Their task is it to estimate a preliminary shipset weight as base for an offer. The weight prediction is the starting point for a possible target or guaranteed weight given to the customer.

The innovations team searches for new materials or production methods that will improve the comfort or quality of the seat. The weight engineer checks these suggestions and evaluates them from the weight point of view. On the other hand, the innovations department will deliver support to the weight department in order to solve overweight problems.

The digital mock-up fits all modules together and checks them for internal collisions or installation conflicts with the aircraft cabin. The weight department exchanges weight and CG data with them, in order to deliver correct models and to receive center of gravity values for the complete seat.

The suppliers receive target weights for their parts and the delivered parts are controlled by the weight department to avoid any exceedance that endangers the achievement of the seat weight target. The weight group prepares weight report forms for the suppliers to assure that they receive the data in a way they can work with.

Weight reports are also delivered from the weight department to the customer, which can be an airline, an aircraft company or an organization responsible for retrofitting an airplane.

These reports can contain preliminary, guaranteed, issued, or weighed weight data.

During the development and production process of a project, changes are made either by customer request or the design department. The weight group supports the change management by validating and checking these changes from the weight point of view. They track all changes in order to keep the weight below the limit and to take measures if the changes might endanger the given targets.

After completing the seat weight status for a specific maturity gate, the weight and CG are delivered to the stress department. They calculate the interface loads for each seat version in the shipset in order to assure that no seat exceeds the allowables given for the aircraft. If there is an overload, the weight engineer, together with his colleagues from the stress and design departments, search for possibilities to reduce the load on the cabin floor. Reduction of the seat weight is not always a solution — more often a CG shift has a bigger influence on the interface loads. This goal can be achieved by moving the complete seat structure above the seat legs outboard or inboard.

As the floor loads allowables become more restrictive due to weight reductions on modern aircraft, fulfilling these specifications with seats containing a lot of in-flight entertainment becomes a big challenge for weight engineers.

RECARO Aircraft Seating is producing seats in different countries, so there is always an exchange between the subsidiaries. In order to optimize the collaboration work, the weight department develops unitary processes, tools, and weight forms. Another task is training employees in other countries or giving new colleagues information about the work of the weight department and their processes.

In order to be always well informed about all developments concerning new materials, production processes, and weight management, the weight department visits trade fairs and conferences. The SAWE membership is also helpful for exchanging experiences with weight engineers from other industries.

The weight department also delivers input to the lessons learned meetings that take place after the completion of a project. They describe their experiences during the whole program and make proposals to improve the performance of the weight management process.

The weight engineer is in contact with nearly each other department of his company — from the design office to the production line, up to the shipping department (for information on the expected weight of parts to be delivered).

4. Tasks of the Weight Department During Different Project Phases

The production process of an aircraft passenger seat can be divided into five phases (App.2):

1) Offer Phase — an airline places a request for a shipset of seats — the weight department delivers an estimated seat weight to the sales department
2) Contract Phase — the customer negotiates a contract with RECARO that includes a target or guaranteed shipset weight — a detailed calculation to get this is done by the weight engineer
3) Development Phase — during the design process, the weight department tracks the weight status of each seat type
4) Certification/Testing Phase — the weight engineer supports the testing and certification department by delivering weight and CG for each seat type in the shipset
5) Production/Shipping Phase — the actual production seat weight is checked against the allowable Maximum Integrated Seat Weight (MISW)

During each phase, the weight engineer stays in close contact with the program engineer/program management to be informed about all changes in the design or equipment of the seat.

It is mandatory to get all information that might have influence on the weight or the center of gravity of the seat in order to take weight saving actions that keep the seat inside the given allowables.

4.1 Offer Phase

The sales department delivers a customer request for a shipset to the weight group. To estimate a weight, the weight engineer needs the airline/aircraft layout with information of the number and type of seats used in the shipset, e.g., front row, exit, last row, or hybrid seats. Hybrid seats are used, if, for example, a triple seat is placed behind a double seat. This means, that one passenger has no backtable in front of his place and so this triple seat needs one in-arm table like that used on front row seats.

All this information and other data about the seat covers (fabric or leather) or the In-flight Entertainment (IFE) installed is listed in the Offer Evaluation Book (OEB).

This book and the reference program used for the new offer are the base for the weight estimation of the shipset weight. The weight engineer combines the data of

the reference program (actual weights of seats already produced for another customer) with the weight values of modules that are different from the reference program (e.g., IFE).

The results are presented in the Sales Weight Matrix that delivers the weight for each seat and the complete shipset including 3% production tolerance.

This data is handed over to the customer (together with prices and time schedules) by the sales department and serves as base for the airline decision.

4.2 Contract Phase

In the contract phase, detailed data for the ordered seats will be defined. This includes target or guaranteed weights, depending on customer's request.

The weight engineer calculates the seat by module including all changes that have been made during the contract negotiations. Base for the weight values are the modules used in former programs that fit to the airline's chosen seat design. To do this, the Seat Definition Book (SDB) is needed and also the contract target weight in order to track the seat weight during the development phase. If the customer asks for a guaranteed weight, this is determined by adding 3% production tolerance and 2% guarantee margin to the calculated seat weight.

These values are displayed in the first issue of the weight report. This report is signed by the weight department, checked by the program manager/engineer, and handed over to the customer.

4.3 Development Phase

During this phase, the seats are developed by the designers. The task of the weight engineer is to collect all information on the seat modules in order to stay informed about the actual status. Each change request (by customer or design) has to be checked; and, if it has any influence to the weight, it must be considered in the calculation.

If a first bill of material is available, the weight engineer uses it as base for the weight calculation. By the help of the RECARO Weight Management System (an Excel-based interface between the company data base and the weight calculation sheet), the weight for each seat type is calculated. The values are delivered by the designer or calculated by the weight manager with the aid of a CAD program (CATIA V4N5).

If prototype parts are available, they are weighed and integrated in the calculation. So each module is updated during the development phase and the actual weight status is controlled by the weight manager by using the weight tracking list.

Based on this information, a revision of the weight report is delivered to the customer (usually each month). It displays the weight status of each seat, of the whole shipset, and the delta to the target weight. The changes to the previous revision are explained, to give the airline or the aircraft manufacturer an overview of the weight development.

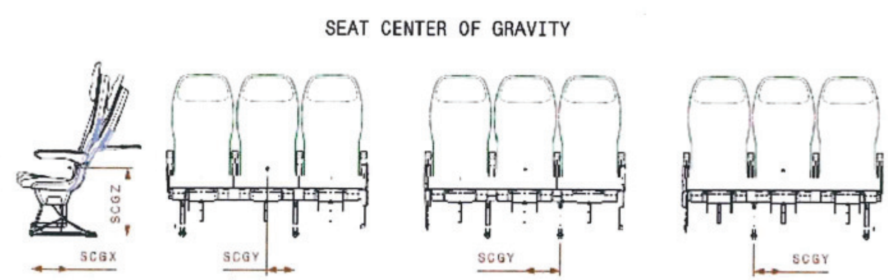


Figure 2: Center of Gravity Definition for Aircraft Passenger Seats

4.4 Certification/Testing Phase

The limits for each seat are the allowable interface loads given by the aircraft manufacturer. To calculate these values, the stress department needs the Maximum Integrated Seat Weight (MISW) and the center of gravity for each seat type. To prepare this data, the weight engineer uses the seat envelope drawing and his actual weight status to calculate the CG of the seats. The MISW is the actual seat weight plus 3% production tolerance.

For each seat module, the x- and z-positions are always identical (Fig.2). The y-positions depend on the aircraft seat track locations, and they are different for each aircraft model.

The seat CG is calculated by combining the CG for each module. The results for every seat type are also displayed on the seat layout drawing.

The testing department chooses the seats to be tested by the results of the interface loads calculation. The seats with the highest loads are chosen for the dynamic testing (14g/16g).

The test seats are not completely equipped in order not to destroy, for example, IFE equipment during the crash tests. So the test seats have to be ballasted in order to reach the calculated MISW and CG.

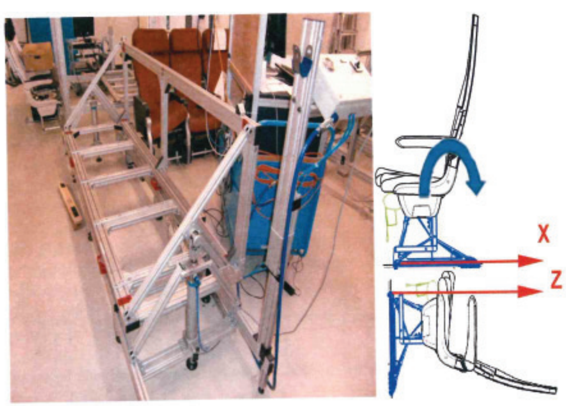


Figure 3: CG Scale

The measurement is done using the weight department's CG-scale (see Figure 3). By turning the seat on the scale 90°, you can measure the x-y and y-z values on the same scale.

The results of the measurement are displayed in the Internal Test Chart and handed to the testing department. The ballasted seats are then transferred to the testing facility.

The CG-scale is also used to check the calculated CG on a fully equipped production seat in order to verify the calculations.

4.5 Production/Shipping Phase

Before producing the first customer shipset, one of each seat type is manufactured for the First Article Inspection (FAI). This is done internally for RECARO and externally together with the customer and/or the aircraft manufacturer.

The serial seats were checked against the calculated MISW. If the actual weight is below the MISW, everything is fine. If a seat is overweight, the weight department has to find the reason. If the cause is not a measurement error, the MISW has to be corrected and the stress and testing department must decide if the new MISW is within the testing limits and that no further actions were necessary. Then the layout drawing and the Interface Loads Report have to be updated.

After the production of each complete shipset, a Final Shipset Weight Report, including every seat part number is prepared by the weight engineer. It shows the delta between the actual weight and the MISW. So the customer has information about each seat and the proof that each seat is within the certification limits.

5. The Historical Seat Weight Evolution

The design and equipment of an aircraft passenger seat has seen many developments over the last decades. New materials and production methods led to lighter seats but additional In-Flight Entertainment and comfort features (kinematics) raised the seat weight again. Figure 4 shows three seats from the last 20 years to give an impression of the evolution. In the year 1991, IFE was not available on the economy class seat so the only "entertainment feature" on board was the ashtray.

In 2003, the seat was equipped with audio function only — a connection for earphones and a control panel for audio channel and volume. 1 kg (2.2 lbs) of IFE was fitted to the seat, but the structure weight itself was 3 kg (6.6 lbs) lower due to lighter parts (e.g., smaller armrests).

Today a standard economy seat carries monitors and handsets (plus boxes for data and power and cables) so the IFE weight rises to 11.5 kg (25.4 lbs). The structure weight is still lower than that of the 1991 version but higher than on the 2001 seat due to more features like kinematics.

6. The Material Distribution of an Economy Class Seat

One of the first ideas to reduce the seat weight is always the change of materials, e.g., from steel to titanium or aluminum. But if you want to know the influence of these steps, you need to know the amount of different materials in a seat. Appendix 3 shows the material distribution of a triple economy class seat.

The main material today is aluminum; steel is still important for heavily loaded parts, e.g. seat fittings. Looking at the three main structure materials only, the distribution is 62% aluminum, 23% plastics (incl. carbon and glass fiber), and 15% steel.

The replacement of the remaining steel inside the seat is difficult, as there are materials necessary that must be lighter but also meet the demanded strength properties.

Reducing the number of fasteners is another way of weight reduction. This can either be reached by bonding parts together or by decreasing the number of parts. The construction of integrated parts is a usual method to do this.

7. Future Challenges – New Materials and Production Methods – The Evolution of In-Flight Entertainment Systems (IFE)

During the development of new aircraft passenger seats, the weight will be a key factor for the market success of the product. So weight reduction is the focus of each seat manufacturer. As described above, the change to lighter materials is one way to reach this goal. These new materials might be magnesium alloys or carbon fibers. The burning properties of magnesium are one problem to be solved when using these light alloys. Carbon fibers on the other hand demand new construction, production, and quality testing methods.

New production methods like laser welding or bonding instead of using fasteners require different calculation methods.

Before implementing these improvements, a lot of development work has to be done to fulfill the specifications for parts used in an aircraft.

Today, the In-Flight Entertainment is not only part of first or business class seats, even passengers in the economy class ask for bigger individual monitors with connections for their own tablet PC or Ipod. Integrating these units into seats without raising the weight is one future challenge for weight engineers.

To reduce the weight connected to these features, the IFE designers include more functions in the monitor itself, like touch screens instead of handsets, power supply included in the monitor, onboard W-LAN, etc.

As the reduction of power supply boxes under the seat is also an improvement for the weight engineer's job, the integration of bigger (and heavier) monitors in the limited backrests delivers new problems. Backrest monitors installed in a high z-position on the seat result in a higher z-CG and, therefore, higher crash loads. The backrest must be strengthened which leads to higher seat weight and so on.

Even with the development of integrated systems, the addition of features will lead to higher IFE weights in the future.

8. Conclusion

The seat is the interface between the passenger and the airline. On the one hand, it is the optical business card of the airline; and, on the other hand, it has a significant influence on the cabin weight and, hence, on the aircraft performance and profitability.

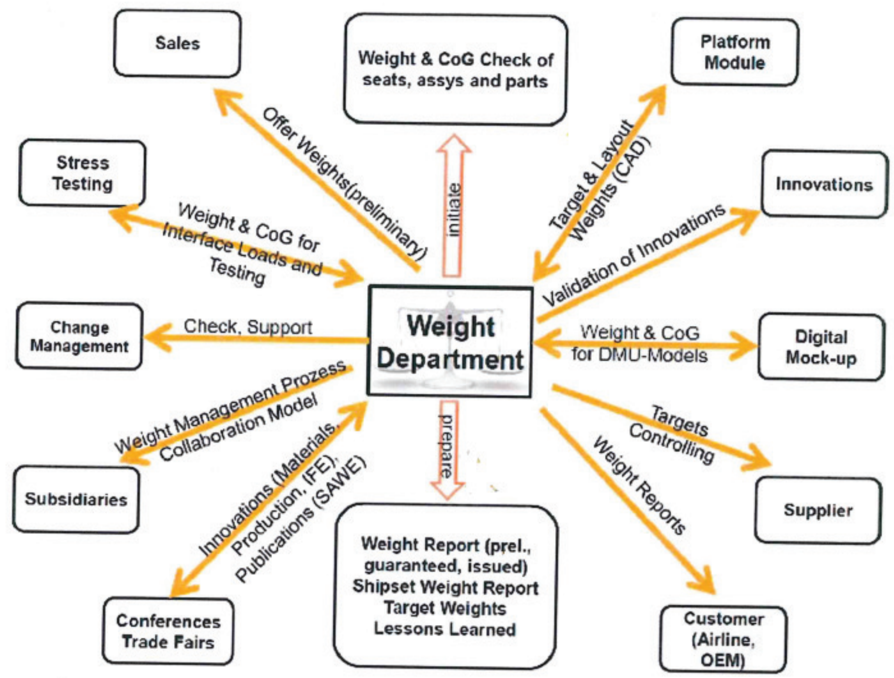
It is the task of the weight engineer to assure that, even with all the new features, the seat weight remains within the limits given by the aircraft specifications.

Type:	BL 3410
Year:	1991
Seat Weight:	49.7 kg (*109.6 lbs*)
IFE :	No (only ashtray)
w/o IFE:	49.7 kg (*109.6 lbs*)

Type:	BL 3510
Year:	2003
Seat Weight:	47.8 kg (*105.4 lbs*)
IFE :	1.0 kg (*2.2 lbs*)
w/o IFE:	46.8 kg (*103.2 lbs*)

Type:	CL 3620
Year:	2012
Seat Weight:	59.9 kg (*132.1 lbs*)
IFE:	11.5 kg (*25.4 lbs*)
w/o IFE:	48.4kg(*106.7 lbs*)

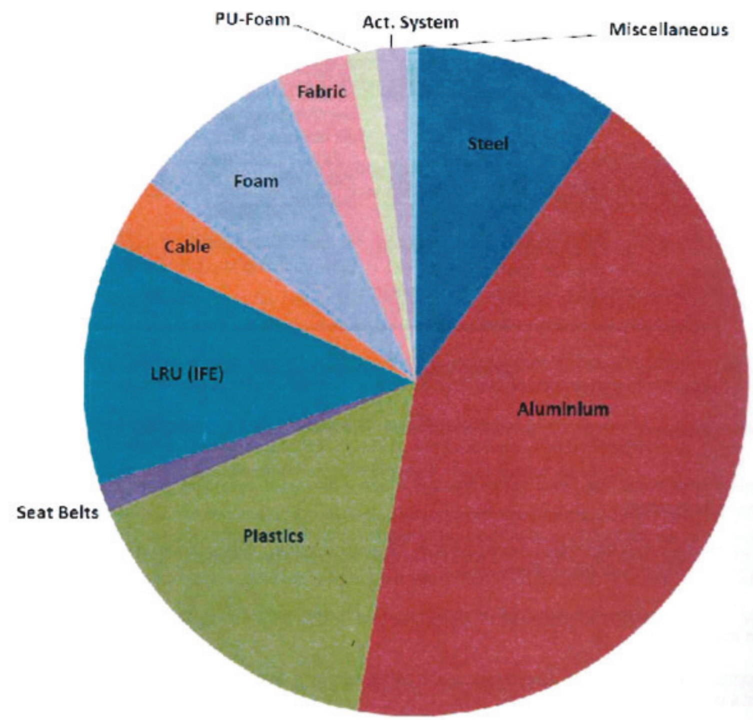
Figure 4: Fictional seats, values given for illustration only, weight depending on aircraft type and customer request



Appendix 1: The Scope of Weight Management

Phase	Offer	Contract	Development	Certification/ Testing	Production/ Shipping
Weight Type	Estimated Seat Weight	Guaranteed Seat Weight (SFE)	Actual Seat Weight (SFE & BFE/IFE)	Maximum Integrated Seat Weight (MISW) Total Test Seat Weight (TTSW)	Final Shipset Weight
Definition	Expected Weight + 3% Tolerance	Expected Weight + 3% Tolerance + 2% Guarantee	Calculated from Bill of Material + Changes	MISW = Actual Seat Weight + 3% Tolerance TTSW = MISW + 25 lbs/pax (literature, life vests, baggage)	Production Weight for all seats in a shipset
Maturity	Estimated	Calculated	Calculated	Calculated	Weighed
Task	**ESTIMATION**	**CALCULATION**	**TRACKING REPORTING**	**CALCULATION TESTING**	**REPORTING**
Document	Sales Weight Matrix	Weight Report (First Issue)	Weight Tracking List Weight Report (Revision)	Interface Loads Report Seat Layout Drawing	Weight Check after First Article Inspection (FAI) Final Shipset Weight Report (for each shipset)

Appendix 2: Tasks of the Weight Department During Different Project Phases



Appendix 3: The Material Distribution of an Economy Class Seat

Author Biography

Heinz Michael Hübner, Dipl.-Ing. (TU) Aerospace Technology, Technical University of Brunswick, is currently a Weight Engineer for RECARO Aircraft Seating. From 1998 to 2005, he was employed as a Weight Engineer at EADS Military Aircraft, Ottobrunn, and Mass Properties Engineer on Phantom, Tornado, Eurofighter, and Airbus. From 2006 to 2007, he was Weight Manager for Eurocopter Germany, German Focal Point for NH-90. He was Weight Manager for Airbus A350 XWB Cabin & Cargo, Hamburg, from 2007 to 2008. In 2009, he started in his current position.