FINAL TECHNICAL REPORT

CONTRACT N° : GMA2-2000-32042

ACRONYM : GOING-SAFE

TITLE : Addressing the Technical, Human & Commercial factors involved in the implementation of 3-Point Shoulder Harness, on all seats, in passenger's aircraft

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PROJECT START DATE : 19/11/01 **DURATION : 16 Months**

Date of issue of this report : 12/05/03

Project funded by the European Community under the 'Competitive and Sustainable Growth' Programme (1998-2002)

Publishable release

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2. Executive Publishable Summary

In the Dynasafe EC. RTD programme, experimental prototypes were built and dynamically tested to validate the concept of a three point shoulder harness, associated to a backrest controlled by an energy absorbing device.
The wanted performance regarding a safe passenger's restraint, and its compatibility with the aircraft floor structure, were positively demonstrated on May 15th 2002 at the CEAT laboratory in Toulouse, opening the way towards a new seating system.

In anticipation of this result, the *Going-Safe* programme started in November 2001 with the objective to progress from experiments into implementation, in addressing the Technical, Human & Commercial factors involved

To that end, the workpackage #1, was devoted to an exhaustive inventory of all the interface requirements to comply with, while attempting to match the new seating system with the existing air transport environment.

Based on Progress Report PR01 (Design Requirements), a preliminary 3D design of a standard triple economy seat assy and its components was made. On this basis, detail design of each component and 2D production drawings were prepared, as well as 3D models of the different economy seat assys of a typical cabin layout shipset were studied and designed (Task 2.2).

The work performed in the Tasks 2.1 and 2.2 of the programme has been a continuous search for the best compromises to match the seats new safety features, with their expected comfort and the airlines commercial requirements. This will appear clearly in the overview of the technical achievements and the questions still pending.

The seat structure and its components have been submitted to a detailed weight and cost saving redesign. The seat structure engineering and design has been made by SD&A, in collaboration with F. Braun, while AVIOINTERIORS was in charge of all styling and comfort aspects.

The design changes and optimizations have then been validated by a technical and economical analysis.

3. Objectives of the project

Essentially the new FAA/JAA rules lay down that, in a range of dynamic impact conditions, a set of performance criteria, related to the human body tolerance to impact loads, must be complied with. In this respect, the most important is the Head Injury Criteria, referred to as the HIC in the automotive as well as in the air transport areas. While the same level of pass / fail HIC has been adopted in both areas, it is only in the automotive applications that effective means of protection have been developped, and are now used in daily routine.

The objective of the "*Going-Safe*" programme is to take advantage of the automotive methodology & experience and to integrate them with the expected results of the DYNASAFE RTD programme (1998-2001) to provide in air transport an equivalent level of passive protection, compatible with the passenger's comfort and the airline requirements.

Historically, to keep the HIC under control in the automobile applications, the first effective means were the Three point shoulder harness (3PSH), at a later stage complemented by the air bag.

Recognizing the obvious effectiveness of the 3PSH, the Dynasafe RTD was dedicated – ab initio – to the feasibility of integrating such a system with a redesigned aircraft passenger seat, compatible with most conventional seating configurations.

In a typical air transport, the most critical seating positions, regarding exposure to head injury in case of an accident, are those facing a bulkhead or a partition, so called " the front row". For aircrafts models certified before june 1988, it was accepted by the JAA that a seat setback 35" from the bulkhead would be sufficient to prevent head impacts from the passengers. Since then, the Dynamic tests performed in the prescribed conditions have demonstrated that this 35" figure is totally inadequate to provide a clear swing to the head of the passenger restrained by only a lap belt, and that the resulting impact could exceed the acceptable HIC.
To comply with the criteria, different solutions have been proposed, like airbags or increased seat setback from 35" to 41"… So far, none of them has been found satisfactory to the airlines.

Supporting analysis and simulation have already confirmed that, in the present stage of Dynasafe, the objective regarding the HIC could be approached at the front row when the seat is installed at the nominal 35" setback, on condition that it would be equipped with an up-graded 3 PSH (backed with adequate shoulder strap inertia reel and energy absorption devices.)

In the automotive area, the problem of the available space in front of the passengers was as much critical. It was not solved however by increasing the space in front but by limiting the head excursion by means of pre-tensioner devices, on the lap and shoulder belts, set to work in the initial phase of the impact, eventually assisted by an air bag. The reduction of the total head excursion, resulting from the belts pre-tensioners alone, might average 3 to 5 inches.

Pre-tensioners devices, automobile style, are currently used for performance evaluation in the Dynasafe test program, however it is clear that their use as qualified equipment in air transport will require a reassesment of their compatibility with airline maintenance, operational and commercial standards. Eventually, either a complete redesign or an alternate concept will be needed.

This is also where the passenger's acceptance of the new protective systems, will have to be explored by the airlines, on the basis of true " in service operations ".

To that end, *"Going-Safe"* provides the guide lines in view of a specific in-flight testing programme, and designs the advanced experimental batch of seats, equipped with 3 PSH & devices, to be ultimately manufactured, certified and installed on board a representative aircraft in commercial operation. However it is understood that such manufacture, certification and experimental phase will fall in the scope of a subsequent industrial programme.

4. Scientific and Technical description of the results

An overview of the technical achievements is described, task per task, herebelow.

4.1. Design Requirements (Task 1)

The first phase of the project has been dedicated to the specification of the design requirements.
The purpose was to define all the design criteria to implement and install the Dynasafe seat prototype into the A320 aircraft cabin.

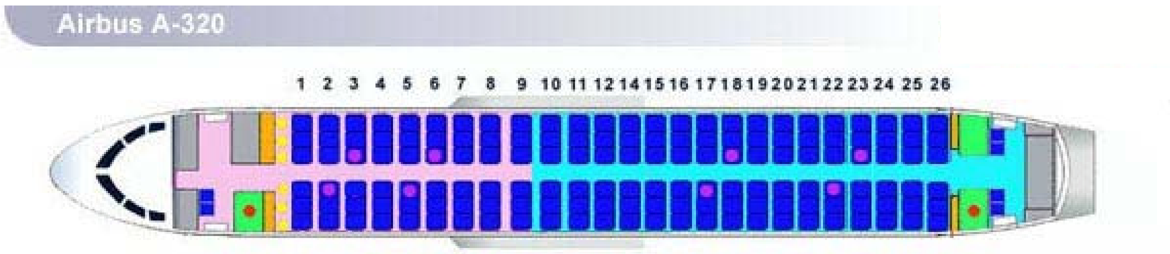


Figure 1 : Typical A320 layout

Following the seat / cabin interference study, the main design changes on the prototypes were :

- Special seat at type III exit, with special outboard spreaders, special back meal table, limited pre-recline and lower seat bottom cushions ;
- Special outboard seat spreaders and backrest in order to respect the inner cabin required clearance ;
- Total seat height limited to max. 45” ;
- Increased space for passenger’s knees by repositioned backrest frame ;
- Provision for replacement of backrest grooved axle by a free rotation axle for full break-over capabilities for stretcher installation (minimum compatible pitch with standard design is 32”) ;
- New spreaders shape in the vicinity of the Discolock location to improve seat accessibility for disabled pax ;
- Reduced seat backrest width for narrow seats, combined with special upper rear leg design for extra-narrow seats.

For reminder, the standard economy seating pitch for the Going-Safe design is 32” for the main following reasons :

- Anthropometric data's - Body sizes & pitches (ref. Airtrack survey) 31" seating insufficient for +/- 50% human males ;

- Going-safe seat offer sufficient knee and living space at 32" pitch for 95%-ile human ;

- On JAA request, a study named upgrading AN64 advised to improve the dimension "A" (seat back cushion to back of seat in front) by 2.2" ;

- Full break-over capabilities of current Going-Safe design starting at 32" ;

The complete study is presented in the Progress Report PR01, delivered in March 2002.

4.2. Design definition (Task 2.1)

The design optimization between the Dynasafe seat prototype and the new Going-Safe seat consists in structural improvements to reduce the weight, the production costs, the assembly time and the maintenance costs, as well as to integrate all the styling and comfort aspects, while considering a range of passengers' size up to 95%-ile.

The design criteria to implement and install the Dynasafe seat prototype into the A320 aircraft cabin were defined in the Progress Report PR01.

Beside the Dynasafe test campaign results, showing the need to have a more rigid seat pan and front beam, a fundamental design issue has been integrated in the Going-Safe structure : the compatibility with the floor deformation condition as required by the FAR 25-562 / AS8049 regulation prior the dynamic certification forward test.

The design improvements made by the Engineering Team on the prototype are reviewed herebelow for each seat sub-assemblies : 3-PSH, backrest, Discolock, spreaders , seatpan, front beam, rear leg, front leg and tie-down fittings.

4.2.1. Review of the seat structure preliminary design (SD&A)

The progress of the design phase in the optimization of the Dynasafe seat prototype design was presented.
The targets of the improvement for the Going-Safe seat are to reduce as much as possible :

- the weight of the seat
- the production costs
- the assembly time
- the maintenance costs

One important new issue has been the integration in the seat primary structure of the capability to accept the distortion introduced by the floor deformation configuration applied on the test set-up and followed by the dynamic forward impact.

The other technical modifications are based on the Dynasafe experience and test results and on the Going-Safe “Design Requirements” report (ref. PR01).

The seat standard model for the design optimization phase is a triple LH economy seat for A320 family aircraft.

4.2.1.1. 3-Point Shoulder Harness design (SD&A with Schroth as Sub-contractor)

Possible optimization of the 3-PSH design with respect to the hardware used in the Dynasafe prototype has been studied .

The position of the inertia reel has been moved up in order to fit the shoulder height of 95%-ile passenger ;

As the position of the inertia reel is fixed in height, the integration of a swiveling function has been considered to provide more comfort and performance of the restraint system but is finally questioned as the shoulder belt webbing will fit the upper torso size if the backrest cushion hole is properly positioned and orientated ;

Tentative re-design of the buckle connecting the shoulder belt and the lap belt has been investigated to make the connection of the shoulder belt to the lap belt part more user-friendly.

The current design is already in use in general aviation seats with a stud on the lap belt connector allowing to clip the shoulder belt latch on it.
As the buckle is positioned at hip level on the passenger’s side, some large people sitting in the prototype found difficult to reach the buckle and to fix the shoulder belt.
Moreover, when the passenger will activate the push-button in case of emergency egress, the shoulder belt will remain connected to one part of the lap belt, surrounding the arm of the passenger and creating an obstacle for an easy evacuation.

To improve the system, SD&A has studied different options of a innovating double entry buckle : double push-buttons automotive style, double lift-lever aircraft style or hybrid model (lift-lever for lap belt with integrated push button for shoulder belt), featuring two separate coloured latches for shoulder belt (blue) and lap belt (yellow).
The action on the yellow latch would release both parts together (needed for emergency conditions) while an action on the blue latch would release only the shoulder belt (to do after take-off in operational use while the lap belt is remaining attached as recommended by the Airlines).

Tentative design proposals were presented with the advantage of a more forward, and therefore more accessible, buckle position (as the shoulder belt connector is fixed into the buckle and not on the lap belt connector anymore) but with their main disadvantage is the probability to operate the wrong latch among both.

Anyway, the development of such devices should be made with the advise of psychologists and ergonomics experts and the introduction of such new restraint system components must be evaluated by the JAA with a demonstration to be made to the regulations authority showing how passengers will escape.

Finally, after evaluation of the existing Dynasafe 3-PSH hardware on a Dynasafe prototype equipped with realistic cushions, it has been concluded that the current existing design is satisfactory at this point :

- the device is simple to operate is not too much expensive ;
- the push-button position is fixed, jammed between bottom cushions and therefore easier to locate ;
- when the passenger will evacuate the seat, the egress direction will be on the same side as the shoulder belt location, so the passenger will rotate around the shoulder belt, remaining attached to the corresponding lap belt part, and will not become an obstacle for the arm as initially expected
- the push-button automobile style will offer a full commonality between 3-PSH release buckle in aircraft and in cars.

4.2.1.2. Backrest

The modifications brought to the backrest design are the following :

- Limited number of components to simplify the assembly procedure ;
- Use of lighter materials ;
- Height of the backrest reduced to limit seat height at 45” max ;
- Shape of outboard backrest fitted to fuselage cross section ;
- The frame has been moved forward in order to provide more space for rear passenger’s knees while keeping the internal panel in place ;

4.2.1.3. Discolock (energy absorbing device)

The modifications brought to the Discolock design are the following :

- Simplified assembly procedure and reduced risk of wrong mounting by introducing symmetrical components ;
- Use of lighter materials ;
- Geometry of casing re-designed to reduce the space and ease access for disabled passengers ;
- Armrests directly fixed to the top of casing ;

4.2.1.4. Spreaders

The modifications brought to the Spreaders design are the following :

- Reinforced web by increased thickness ;
- Upper and lower flanges on the same side to reduce the machining production cost ;
- Improved connection between upper flange and top covering plate ;
- Upper shape of spreaders re-designed to ease the access to the seat and to allow installation of an in-arm table ;
- Outboard spreader re-designed to avoid fuselage interference ;

4.2.1.5. Seat pan

The modification brought to the seat pan design is an increased thickness of the honeycomb panel in order to increase the rigidity of this part.

4.2.1.6. Front beam

The modifications brought to the Front beam design is to design it in one part to be produced by extrusion process.
The aluminum alloy must be selected to be suitable for extrusion and strength.

4.2.1.7. Rear leg

The modifications brought to the Rear leg design are the following (see pictures in appendix) :

- Production process will be machining or forging or both ;
- An alternate design of the Upper rear leg part must be adapted to the central spreaders–rear legs connection for the extra-narrow at the rearmost row in the A320 aircraft ;

4.2.1.8. Front leg

To allow the seat rigid structure to accept the pre-test track distortion ($\pm$ 10° of pitch on one track and $\pm$ 10° of roll on the other), the proposed solution is to introduce an extensible front leg and a spherical bearing at tie-down.

On conventional seat structures, no special provisions are required to reduce the stresses introduced by the floor deformation. But to sustain the higher load level introduced by the shoulder belt during the impact, the seat primary structure must be very rigid, which make the pre-load conditions from the application of the floor deformation too high in the structure to be able to sustain the following dynamic forward impact.

This was confirmed in begin of June by the load measurements made on the floor deformation test bench at Aviointeriors with one Dynasafe existing prototype on which the full track distortion was applied according to the regulation.
Therefore, an additional system is needed in the seat legs in order to reduce the pre-loads in the primary structure.

This device would have the following features :
- remain not extended in usual conditions ;
- has a capacity of one-way extension following pitch distortion of the floor track ;
- stays extended during the impact ;

4.2.1.9. Fittings

The modifications brought to the tie-down fittings are the following :

- Front fitting : introduction of a spherical bearing for the roll issue ;
- Rear fitting : replacement of 3-studs fitting by a 4-studs fitting to spread the load on the track lips

4.2.1.10. Standard triple seat model assy

A preliminary design of the economy triple seat model has been made by SD&A in 3D, using Catia V5 sofware.

4.2.1.11. Structural resistance validation by FEM analysis

The structural resistance of the preliminary seat design were validated by FEM analysis

4.2.1.12. Seat installation commonalities between BAe146 / AVRO RJ85/100 and Airbus A320 family aircrafts

As BAE Systems decided to abandon the AVRO RJX development programme end of 2001 and therefore no new AVRO aircraft models will be produced in the future, the study of commonalities was abandonned.

4.2.2. Seat general styling and comfort design definition (AVIO)

The styling, comfort and equipment definition and design must be integrated in the seat structure.

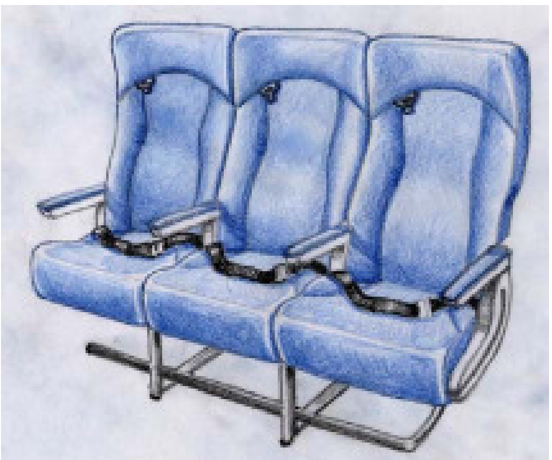
AVIOINTERIORS is in charge to design the following items :
- armrest design,
- rear table design,
- cushions and covers,
- paddings,
- integration of 3-PSH backrest upholstery,
- end bay,
- IFE provisions.

Usually, the development of a new aircraft seat model starts with the styling definition, and then the structure is designed to fit within.

For the Going-Safe seat, the structure has been designed before the styling definition, which gives less freedom to the stylists for the future brand new look of this new seat.

AVIO started the general styling and comfort definition by asking one of their stylists to prepare several artists' impression drawing views of tentative look of the Going-Safe and came up with 3 different styling proposals that could be implemented in the Going-Safe design.
The main differences in the 3 proposals are the spreader end bay side panels and the armrest shape.
The proposed colours were blue, white and grey.

Detailed artist's renderings drawings of the upholstery components were prepared by AVIO :



4.3. Detail design (Task 2.2)

Based on the standard triple economy seat model designed during the preliminary design of task 2.1, the design of each component has been detailed and 2D production drawings have been prepared.

The complete study is presented in the Progress Report P.R. 02&03, delivered in February 2003.

4.3.1. Review of the seat structure detail design

In comparison with the above preliminary design, the following changes were made in view of an additional optimization effort, mainly regarding weight savings aspects.
The total seat structure width has also been slightly reduced to include the thicknesses of the endbays and armrests fairings, leading to a 62'' standard configuration.

3-Point Shoulder Harness design (with Schroth Safety Products as Sub-contractor)

After considering the pros and cons of several design proposals to improve the 3-PSH and discussion with Carl Schroth, General Manager of Schroth Safety Products who provided the hardware in the Dynasafe program, the following components were retained for improvements :

- Buckle support ;
- Lap belt length adjuster ;
- Small persons comfort accomodation ;
- Buckle design

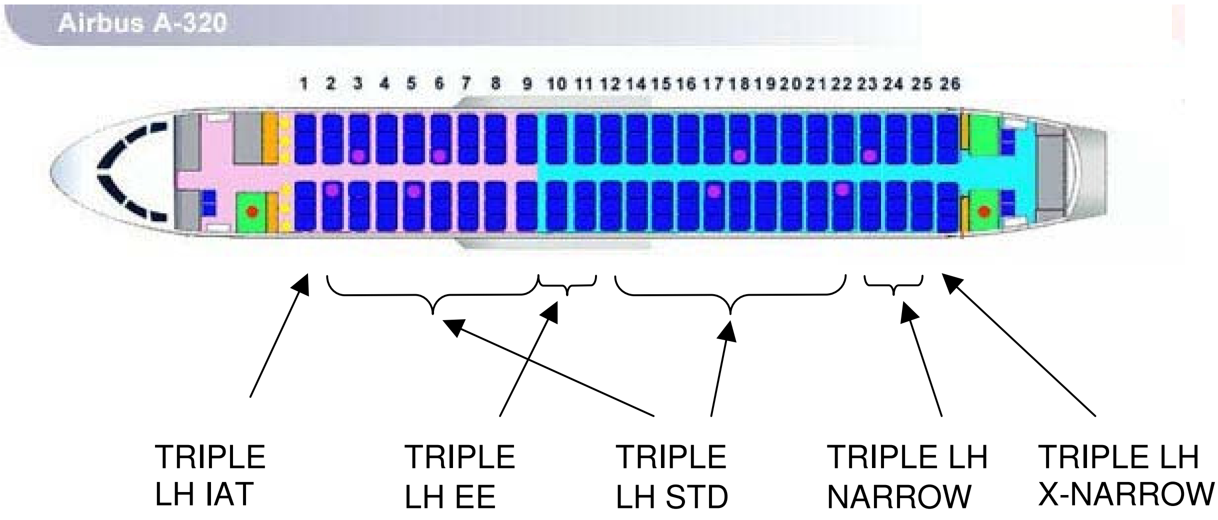
Additional detail design modifications have been made to the design of Backrest assembly, Discolock assembly, Lower primary structure (''shell'') assembly, Seat leg assembly, Standard triple seat model assy.

4.3.2. Nomenclature / Bill of material

Each part of the seat structure has been designated by a Part Number, following the usual SD&A drawing nomenclature procedure :

The different seat types to equip a complete shipset of typical Airbus A320 & A321 aircraft cabins have been listed and designated by a seat P/N
Note that front row seats models for Airbus A340 and Boeing B777 aircrafts have also been included in the list, following the analysis of the exploitation perspectives.

The common seat models between A320 & A321 are shown herebelow :



All of the above LH seat models were designed in 3D (RH models are symmetricals), but only the production drawings of the TRIPLE LH STD seat models has been detailed.

Major sub-assemblies of TRIPLE LH STD

- BACKREST ASSY LH INB STD
- BACKREST ASSY LH INB NARROW
- BACKREST ASSY LH OUTB NARROW
- DISCOLOCK ASSY LH MID
- DISCOLOCK ASSY LH AISLE
- SHELL ASSY LH STD
- SEAT LEG ASSY LH STD
- SEAT LEG ASSY RH STD

4.3.3. Triple LH STD seat Production Drawings

All production drawings, and corresponding P/N list, of the TRIPLE LH STD seat (assembly, sub-assemblies and parts) have been prepared.

4.3.4. Structural analysis and validation by FEM calculation

The structural resistance of the STD seat model and some of its components has been validated by static FEM analysis for the major load cases :

- Backrest – 16g FWD deceleration
- Discolock Casing, Linear Lever, Grooved Shaft – 16g FWD deceleration
- Primary Structure – 4g Sideward
- Primary Structure – 9g FWD static
- Primary Structure – 16g FWD deceleration with floor deformation

Note that the validation of the dynamic behaviour of the seat structure has been carried out by TNO within task 3.1. The results are described in the P.R. 04 report.

4.3.5. Weight & Cost study

A weight and production cost assessment has been prepared for each component of the TRIPLE LH STD seat model.

4.3.6. Seat Maintenance aspects

Exploded views of the TRIPLE LH STD seat model, detailing the different components of the seat assembly, are given in appendix IV of this report.

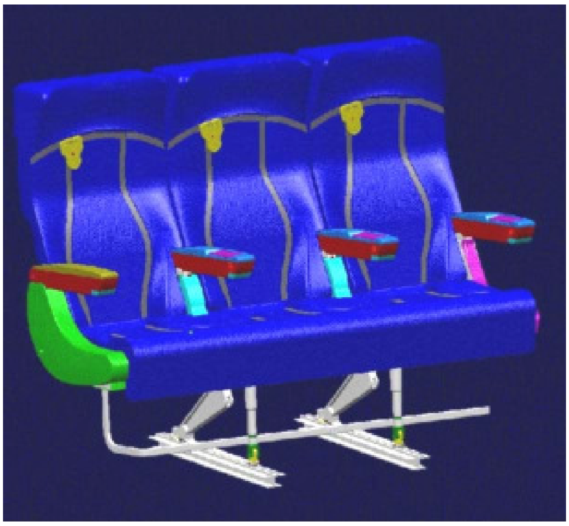
The aircraft seat maintenance workshop of Sabena Technics company have been visited.
Typical seat maintenance toolings and storage area for replacement parts were observed

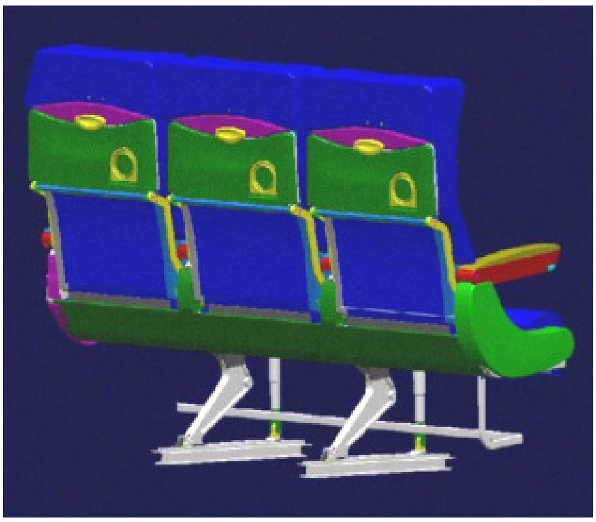
4.3.7. Seat Assembly procedure and tooling

The typical seat assembly procedure has been studied, using the KANBAN method, and several documents were prepared.

4.3.8. Styling and Comfort items detail design (AVIO)

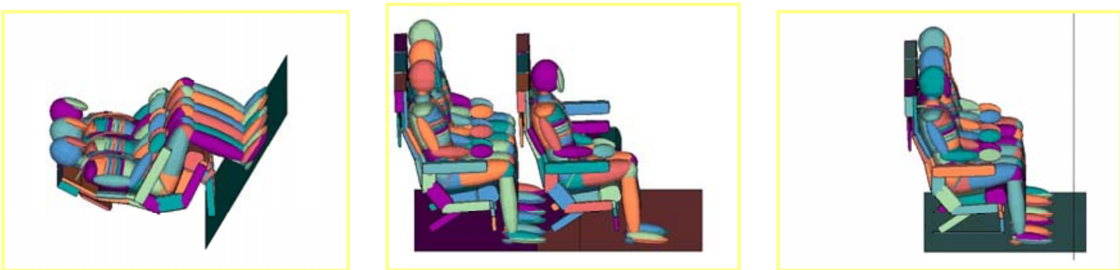
On the basis of the Styling and Comfort items preliminary design defined by artist's renderings during task 2.1, detailed 3D design and drawings have been prepared by AVIO :





4.4. Concept validation (Task 3.1)

Dynamic simulations have been performed with the Going-Safe seat design in order to validate the engineering changes made to optimize the prototype structure and to evaluate the dynamic behaviour of the seat structure, prior to the certification test campaign, for several crash conditions, load configuration, and dummies' parameters (HIC value, head trajectory, femur and lumbar loads, leg injuries,…) with respect to the limits accepted for the certification :



Simulation models in different testing configurations

4.4.1. Head / bulkhead clearance

The clearance of the occupant's head with the bulkhead put on a distance of 940 mm from the rear tie-down point is given in below table. The minimum clearance found is 116 mm for a certification load case with floor deformation applied.

Configuration		LH seat (window)	Middle seat	RH Seat (aisle)
Without Floor Deformation in [mm]				
Standard	**3x95%ile**	167	177	157
Standard	**3x50%ile**	**261**	**261**	**236**
Standard	**3x 5%ile**	433	433	433
With Floor Deformation in [mm] (50%ile occupant only)				
Standard	**3x50%ile**	**132**	**139**	**118**
Narrow	**3x50%ile**	132	137	117
Extra narrow	**3x50%ile**	128	129	116
Dual	**2x50%ile**	139	152	(No seat)
Lap belt only HIC values in [s] (upright seating position)				
Standard	**3x95%ile**	1007	929	1030
Standard	**3x50%ile**	**430**	**418**	**460**
Standard	**3x 5%ile**	392	397	370

Head – Bulkhead clearances and HIC values
(Bulkhead positionned at 35'' nominal setback from Seat Reference Point)

If the occupants are restrained with a lap belt only the head impacts the bulkhead. The head injury values are for the large male (95%ile) occupant close to or over

the injury criterion limit of HIC 1000. The interference of the head trajectory with the bulkhead is approximately 55 mm for the 50%ile and 140 mm for the 95%ile.
If the seat row is closer to the bulkhead the HIC values will be significantly higher as shown in the design optimization simulations where an interference of 77 mm resulted in a HIC value of 2250 for the 50% occupant.

4.4.2. Head injury criterion (HIC) values in row to row

The contact of the occupant's head with the rear side of the backrest of the seat in front can occur at different locations: at the foam padding above the meal-table, at the meal-table or its edges and backrest base below the meal-table in case the backrest is folded forward completely. The later contact occurs in conventional interior configurations when the deceleration is enough to bring the backrest in complete fold forward position. The HIC values predicted by the simulations are summarized for all the three-point shoulder harness cases, the average male (50%ile) occupant and the Lap belted only cases. All three-point shoulder harness cases are simulated with a not occupied row in front. This is critical case because if the seat in front is occupied the seatback moves forward. As a result of this the contact will be less sever. For reference the lap belted only cases are summarized.

Configuration	LH seat (window)	Middle seat	RH Seat (aisle)
All 3-Point Shoulder Harness cases			
Pitch 34”	**288** (EE 35 3x95) Foam and later table	**312** (EE 35 3x95) Foam and later table	281 (EE 35 3x95) Foam and later table
Pitch 32”	264 (Std 3x95) Foam	240 (EN 2x95) Foam and later table	269 (EN 2x95) Foam and later table
Pitch 30”	248 (Std 3x95) Foam	241 (N 2x95) Foam	**311** (N 3x50) Foam
50%ile occupants (full occupied seat row)			
Pitch 34”	79 (EN) No significant contact	84 (EE 35) No significant contact	135 (N) Foam and table edge (minor)
Pitch 32”	135 (Std) Foam and later table	145 (Std) Foam and later table	193 (N) Foam and later table
Pitch 30”	216 (EN) Foam	237 (N) Foam	**311** (N) Foam
Lap belt only (95/95/95%ile, 50/50/50%ile or 5/ 5/ 5%ile all in upright seating position)			
About configuration of the row in front see note	Seat in front not occupied	Conventional seat in front not occupied	Seat in front occupied (50%ile)
Pitch 34”	1074 (3x 5) Table	4508 (3x95) Backrest base	**2213** (3x50) Table
Pitch 32”	1063 (3x95) Foam and later table	**6755** (3x50) Backrest base	1435 (3x50) Table
Pitch 30”	**1400** (3x50) Foam and later table	5651 (3x50) Backrest base	1654 (3x 5) Table

Head injury HIC values and contact indication in row to row configurations
Std = Standard; (E)N = (Extra) Narrow; EE = Emergency exit row

Note: In all the 12 explored cases the row in front has different configurations per seat :
Left hand seat : GOING-SAFE seat with energy-absorbing hinge. Not occupied seat.
Middle seat : Seat with no energy-absorbing hinge, not occupied. To simulate conventional seat configuration: Seat back rotating forward driven by deceleration pulse.
Right hand seat : GOING-SAFE seat with energy-absorbing hinge. Seat occupied with 50%ile occupant.

All GOING-SAFE three-point shoulder harness seat configurations show HIC values as low as 312 maximum for all occupant sizes. The three-point shoulder harness, the backrest hinge energy absorber and hard foam padding above the meal-table provides ample head impact protection to pass a certification test with a 16G-deceleration pulse.

The LAP BELT ONLY cases show HIC values far beyond the criterion of 1000. If the seat in front is not occupied (see left hand seat simulation) the occupant contacts the seat in front on the foam and later the table. The predicted critical HIC is 1400 for an average male 50%ile occupant with a 30-inch seat pitch. If a 50% ile occupant takes the seat in front (see right hand seat simulation), the head contacts fully on the table. The critical HIC value predicted becomes 2213. If the backrest, of a non occupied seat, rotates forward due to the pulse deceleration like in a conventional aircraft interior (see middle seat simulation) the head contacts the backrest base under the table. At this seat structure location there is no padding to soften contact of the high-speed almost perpendicular impact. The resulting predicted HIC value is 6755.

From the research presented in the report the main conclusions are:

- The Going-Safe concept will pass the vertical certification test ;
- The belt loads show ample safety margin with respect to the injury criterion limit ;
- The Going-Safe floor loads show straightforward compliance with the regulations with regards to floor strength ;
- None of the three point shoulder harness cases did show contact with bulkhead ;
- For all the three point shoulder harness cases in a row to row configuration the head injury criterion value is smaller than 320 (this applies for all occupant sizes) ;
- Femur compression loads show ample safety margin with respect to the injury criterion limit

The technical confidential content of task 3.1 has been included in the P.R. 02 & 03 ''Design definition and execution'' report.

4.5. Cost Benefit Analysis (Task 3.2)

A review of the Cost Benefits analysis, prepared by AVIOINTERIORS is given herebelow, based on the findings of the cost and weight analysis, the comparative assessments with conventional seats, and as well all and all comments received at the Aircraft Interiors Expo 2003.

Fore more details, see appendix report P.R. #04.

2.2.1. Going-Safe seat vs market

- **Safety matters**

In terms of safety no comparison is possible between the traditional lap belt and the 3-PSH.

The lap ventral belt is not able at all to restraint the passenger's torso, and consequently the head, that is the most critical part of the human body subject to possible deadly injury impacts.

The 3-PSH is safer for the passenger when seated in any position onboard the airplane, because also in the row to row condition is capable to avoid any potential minor impact.

From a psychological point of view the passenger is bringing into the aircraft cabin the idea of safety taken from his experience as car driver, the 3-PSH is certainly what he can consider the closest.

- **Weight and cost analysis**

The summary of the Weight and Cost Analysis study is the following :

<u>Weight analysis</u>

The *Going-Safe* seat is:

- 75% <u>lighter</u> than a Rigid Front Row Seat ;
- 12.5% and 5% <u>heavier</u> than a Standard Front Row Seat and an Airbag Seat respectively.

An airline would consider <u>negligible</u> the above weight increase because of the limited quantity of seats of that kind, in particular consideration that we are talking about wide-body aircraft.

4.5.1.1. Cost analysis

→ The *Going-Safe* seat is competitive, even if its production cost is slightly higher than a Rigid Front Row Seat and an Airbag Seat.

→ On the other hand the *Going-Safe* seat is not competitive, if compared with a Standard Seat.

- **Seat maintenance cost**

It is actually difficult to evaluate, with few data available, the maintenance cost of the Going-Safe seat.

Nevertheless we can state that roughly the maintenance cost of this kind of seat, excluding the "Discolock" and the Inertia Reel devices, is comparable with the reference seats.

The Third Belt and the more complex Buckle would not contribute significantly to make difficult the seat maintenance.

But inspections and scheduled replacements on "Discolocks" the airline operations, because these equipments are not easily accessible onboard.

Another component, subject to inspection and maintenance, is the replacement the end-bay needs to be removed to have access to.

All above considerations imply an higher maintenance cost for the Going-Safe seat.

- **Seat comfort and styling**

The actual seat structure of the styling when compared with a conventional seat, mainly because of its bunk type frame for both seat and back structures.

Great attention has been paid in providing enhanced style and comfort comparable and even better than airline currently used seat models.

Results are evident for the general appearance of the Going-Safe seat as noticeable from the design details shown in the following pages.

Also the comfort has received dedicated attention in order do not penalize the passenger because of the specific safety features of the Going-Safe seat.

Some improvement in greater extent could be eventually obtained from a redesign of the backrest frame passing from the actual necessarily flat composite sandwich panel technology to the more ergonomic free forms obtainable with the pre-preg composite lay-up technology.

2.2.2. Direct Sales potential

- Direct sales are directed to OEM and to retrofit markets

  - Sales to OEM market (to the aircraft manufacturers for installation on new aircraft)

    Actually (year 2003) the general airline market is depressed for economic and political reasons, and it will remain same way at least until 2004, but hopefully it will recover shortly the positions of ante-Sep 11 2001, then the long-term outlooks of both aircraft manufacturers provide an annual increase of an average 5% for the next 20 years.
    Actualy (year 2003) the worldwide aircraft seat market requires no more than 75,000 seat places per year, 80% of which are economy class.
    Therefore the worlwide OEM aircraft seat requirement can be estimated from the actual 60,000 economy class seat places to increase pogressively to 120,000 – 150,000 economy class seat places durung the next two decades.

  - Sales to retrofit market (to airlines for installation on existing aircraft by replacing obsolete seats)

    More difficult is the evaluation of the aircraft seat retrofit market due to individual decisions taken by any single airline based on the worldwide economy conditions, conditions of the regional markets where the any single airline operates. For the scope of the present analysis, it is enough to state that the economy class aircraft seat requirement by the airline retrofit market is at least at the same level of the quantity estimated for the OEM market. From 60,000 economy class seat places of today to the 150,000 forecast of the next 20 years.

- Global market trend review

  "In view of challenging market conditions, we have a responsibility to take aggressive actions to continuously improve our competitive edge and align our production rate with market demand."

  This is a direct quote from Bombardier Aerospace president Pierre Beaudoin why the company was laying off 3,000 people.
  Times are hard in Canada. Times are hard everywhere, in fact.
  But this could have been the output of virtually any aerospace company in the world.
  Production rates are low, new orders terribly hard to come by, cancellations look increasingly likely and everyone is having to look very carefully at where, and how, they can effect savings.

  It seems like everything is being piled onto the air transportation industry.

We have recession and act of terrorism , both of which inevitably contribute to fewer people wanting to go on a flight and therefore fewer airlines wanting to buy new aircraft.

We have had a war. Fortunately, the fighting part of the war seems to have been done. The conflict is largely over, but that outcome was not always so certain.

The travelling public may be rather more willing to go on a flight now, but there is still the question of how much it costs.

There is, after all, a recession. This sort of thing actually goes around in circles, and the new thing to make it all even more interesting is that now we have this killer bug and the perception in the West is that anybody really doesn't want to fly to the Far East, SARS and the airlines are doing their utmost to reassure people.

For the commercial aerospace industry to thrive, there has to be demand for flights and right now, for a whole raft of reasons, that demand is just not there.It has not been there for some times either.

One can see the consequences in the figures. At the end of the first quarter of this year, the large commercial currently stands at the same level as it was in late 1997. The major difference is that back then the backlog was steadily increasing. Now it is rapidly going the other way.

Production rates are down too. One can say, with absolute certainty, that whatever happened in any given month last year, production will be less in the same month this year.

The manufacturers are now very uncertain about prospects for 2004. All the talk is for a long haul before any form of recovery begins. There seems to be a feeling in the industry that the market will start to improve in 2005 but that it will then take a very long time to get back to the same sort of levels we had in 2000 and 2001. Indeed, the market might not get back to those levels before the end of the decade.

This is not really so surprising. It is, after all, precisely what happened after the last Gulf War. The airline industry took years to improve and increased ordering of start to happen until the mid-point of the decade. The peak, in 2001, actually coincided with the 10th anniversary of Iraqi militia being driven out of Kuwait.

All the indications are that it will take time for the industry to recover. By the same token, there are likely to be some major changes in the product offerings.

The very low backlog position of the 757 and 767 programmes, for example, tend to indicate that those programmes might killed off in the not-too-distant future. Boeing will, after all, need production capacity for the 7E7 mid-range transport if the board of directors approves an authority to offer. The company wants to start selling the aircraft next year with a launch in the summer.

Despite all the secrecy about the 7E7, the plain fact is that the company needs something to fill the 757-767 gap. This is a progamme that looks more likely to get off the ground every day and it is probably as important to the company, if not more so, than the 777 was. Boeing is very serious about this aircraft. They have filed for type and production certificates with the FAA and JAA and are currently looking at possible manufacturing sites.

If it is a success, it will change the company's fortunes. However, as exciting as a new aircraft program is, there is a lot of ground to cover before production actually begins. It may be some years before the first 7E7 rolls out.

The situation repeats alike for Airbus and its brand new aircraft model A380.

In the meantime, we have to continue to endure this downturn.

- Opinion survey

An Opinion Survey among the professionals involved in the aircraft field has shown encouraging results, giving fuel to the enthusiasm of the participants of this program.

Some of the airline managers consulted during our survey found the 3- PSH seat concept very innovative, and the majority of them found approach at least interesting.

Almost everybody is interested in knowing further achievements, if any.

Unfortunately we did not find any launching customer yet!

4.6. Overall Safety Assessment (Task 3.3)

A summary of the Safety assessment report is given herebelow.

4.6.1. Programme of Assessment

The Safety assessment is based on the reporting on discussions with relevant authorithies and the comparison between 3-PSH solutions vs competitive systems.

4.6.2. Reporting on discusions

- **JAA CSSG meeting**

  The Going-Safe program was presented at the annual JAA Cabin Safety Steering Group in London on June 19th 2002.
  This group gathers professional experts from JAA, Aircraft manufacturers and Airlines, as well as FAA observers.

- **Professor Helen Muir, Pro-Vice-Chancellor of Cranfield University**

  Helen Muir is the Professor of Aerospace Psychology. She has an MA in Psychology,a PhD from the University of London and is a Chartered Psychologist. (see annex 2)

  She has been called by the team of ***Going-Safe*** to discuss the psychologic aspects of the 3 PSH, in particular regarding its acceptance by the Passenger's and cabin Crews in normal as well as in emergency conditions.
  The meeting was set on November 20th 2002 .

- **FAA - Aircraft Certification Service**

  International Field Representatives:
  Mrs. Monica L Nemecek – Transport Airplane Directorate
  Mr. Gregory Edwards – Aircraft Engineering Division

  The attendance of Mr. Ir. Marc De Smet, Belgian CAA Certification Director was requested by Mrs. Nemecek in anticipation of certification procedure relative to the *Going-Safe* seats.

  The meeting was set on December 12th 2002. The SNPRM 14 CFR Part 121, dated October 4th. 2002 – Acceptance by the Industry (Aircraft, Seats manufacturers & Airlines) was discussed as well as the forecast on the effective date of the final rule.

4.6.3. Comparison of 3-PSH vs Competititve systems

Prior to the call for demonstration in the Dynasafe programme, back in 1994, the Directorate for Transport DG XII initiated a feasibility study to assess the problems and potential benefits associated with the introduction of the three point shoulder harness in Commercial Air transport.

In the process, a table was set-up comparing the performance of the alternates means availables or under study (ref. Annex 3). It may be observed that in 1994, not less than 9 alternates means were in competition
We are in 2003 and only three options are still considered :

a) Seat with lap belt only
b) Seat with inflatable lap belt
c) Seat with 3PSH

All three options are equal in front of the legal status of the JAR regulations. As their effectivity is planned to become applicable to all seats, in all aircrafts models certified after 1958, within the next 14 years after 2003, it is not proposed to speculate in this chapter on the current and provisional derogations per aircraft, per year of production and per seating installation.

It is clear that the JAR 25-785 is a general rule governing the protection to be provided in respect of the inertia forces specified in JAR 25-561 and JAR 25-562. The rule is applicable at any time during a scenario of emergency landing.

Compliance with the rule is described in the SAE AS-8O49.

- In static tests conditions the load must be sustained by the seat structure (as well as the protection of the passengers) for a duration of 3 sec.
- In dynamic tests two different tests configurations and pulse are prescribed and minimum performance standards must be demonstrated.

The above rules address complete seats assy, including the occupant restraint system.
There is nothing in the above rules, that dispense the seat manufacturer to show compliance of the complete seat with the totality of the static and dynamic impact conditions set forth.

Therefore, a seat equipped with an inflatable belt must be qualified also for all static and dynamic conditions, whether or not the belt is inflated.

- **Lap belt only equipment - the standard for the last 60 years**

While it is not satisfactory at front rows, nor in transversal staggered seating, there is a consensus in the industry to consider that, in well defined conditions of seat pitch and appropriate padding, the required HIC (under 1000 units) can be demonstrated with a 50%ile dummy.

This demonstration doesn't consider the totality of the 5%ile to 95%ile passenger's size range, in fact none of them except the theoretical 50 %ile model. All passenger's must have a seat that accommodate their size but only the 50 %ile model is demonstrated to be safely restrained.

The range of the seating pitch covered by the tests & analysis make the problem worst . Indeed, for commercial or technical reasons, an airline might be tempted (or compelled) to install one or more seat rows out of the certified pitch range. Gradually the certification basis might erode and get out of control.

An exhaustive simulation and analysis has been carried out to compare the relative performances of the lap belt only / the 3 PSH by the TNO Partner. It is the subject of Task 3.1. The conclusions are 100 % satisfactory, in favour of the 3-PSH

- **Inflatable technology**

In total disregard for the needed versatility in unpredictable impact conditions, the competitive sytems based on inflatable technology are typically disarmed in front of successive impacts. Indeed, their energy absorption principle requires immediate deflation within the impact duration. It follows their genuine unability to perform in a second impact.
It results that, to make the best use of this " one shot " performance, the designers of such systems have to evaluate and set the triggering G level at which their system will be expected to perform.

- Should they want to pass the criteria of test N° 1, they might decide to set the inflation at 6 G, but then how would they perform if the test n° 2 conditions were applied within the next 0.040 sec ?

- Should they set it at 12G, it would result that in all conditions involving less than 12G, the seat occupant would be restrained by a lap belt only with the risk of a head impact exceding the 1000 mark (HIC) .

- **3-PSH solution**

Resulting from the above discussions & exchange of opinions, it appears that the proposed 3-PSH, when installed on a seat structure properly designed and manufactured, is the most advanced seating equipement that an airline can provide to enhance the safety of its passengers.

✓ It complies fully with All the requirements of the JAR-25 785 and derived tests procedures per JAR 25.561 & 562 including the protection of the Children and the lower legs.

A distinction must be made in respect of the installation :

<u>At front rows</u> : The performance is 100 % satisfactory when testing at 35" distance from seat to bulkhead. No head impact means no need for further

HIC analysis. Without impact, due to the restraint of the upper toprso by the shoulder belt, a HIC of 250 has been recorded.

Row to Row : The resulting HIC must be analysed and documented. It will depend essentially from the seating pitch, the passenger's size and the capacity for energy absorption of the padding on the aft face of the backrest.

In any case the effect of the discolock on the passenger's head excursion, and relative velocity, will always result in a reduction of the HIC, should any impact occurs. An analysis of Dynamic tests records has shown that with a 50%ile dummy, at a 32" pitch, the HIC is 500 units (where 1000 is the acceptable limit).
This performance is confirmed by the TNO report on "Injuries assessment results" vs. parameters, dated 6 february 2003.

- ✓ It exceeds the requirements by solving the issue of the " brace position ".
- ✓ It exceeds the requirements by keeping positive performance under successive impacts conditions
- ✓ It is compatible with Airlines operational and maintenance practises.
- ✓ It is compatible with existing and future aircrafts floors
- ✓ All criteria for certification are included in the existing SAE AS 8049
- ✓ A specific TSO Authorisation could be issued to cover the manufacture of this equipment on a worldwide scale.
- ✓ Extension of application on a worldwide scale will allow mass production methods to be applied to reduce the cost penalty.
- ✓ By a generalised installation of the 3 PSH, the world airlines would be on even terms in their treatment of their passenger's safety .
- ✓ It is readily acceptable by the passengers and proper use is easy to check by the cabin attendants.

5. List of deliverables

The following table gives an overview of the project deliverables and their issue dates.

Overview of Deliverables				
Deliverable No.	Delivery date	Output from WP.Nr.	Nature of Deliverable	Delivery Status
D1	Month 3	WP1	Progress Report PR01 : Design Requirements	P*
D2	Month 7	WP2	PR02 : Design Definition	R*
D3	Month 8	N/A	Mid-Term Assessment Report	R*
D4	Month 13	WP2	PR03 : Detail Design	R*
D5	Month 14	WP3	PR04 : Technical & Economical Assessment	P*

* P = Public issue
* R = Restricted issue

As mentionned previously, the Progress Report ''PR02'' covering the Design Definition task activity is actually included in this Mid-Term report, while the description of the remaining work results (mainly the validation by FEM analysis) will be merged with in the Detail Design Task report ''PR03''.

The report PR01 ''Design requirements'' is basically an inventory of all requirements that have been identified as issued by the main Authorities and Air transport managers, having either the use or the responsibility for aircraft seats introduction in their fleet.
Besides those Authorities we have the opinions , the passengers and the professional co-users, the cabin attendants and the maintenance ground crews.
This report is a public issue and the Going-Safe management welcome any comment that could be made by the above groups or individuals.

The reports PRO2 and PRO3 ''Design defintion and execution'' are implementing in the design of the new seats, all necessary engineering up-date to reach a status of a commercial product, complying with all identified requirements. The status of these two reports is "restricted issue" . It is the basis of the knowledge resulting from the Going-Safe programme.

The mid-term assessment report : is a critical review of the achievements made during the first half of the project against planned milestones

The report PRO4 ''Technical & Economical assessment'' gathers the analysis of the Safety and Cost benefits of the proposed 3-PSH solution for aircraft passenger seats.

The Final Technical report : is a review of the technical achievements made during the project, together with a Technological Implementation Plan.

6. Comparison of initially planned activities and work actually accomplished

The activities followed closely the project programme but encountered some delay.

Indeed, the Going-Safe programme was started in Nov. 2001, in anticipation of the results expected from the Dynasafe programme.
In spite of steady progress observed in Dynasafe during year 2001, it was not before May 15th 2002 that the final dynamic test at the CEAT confirmed the ultimate value of the experiment.

Meanwhile the Going-Safe initial task, WP#1 "In flight operations requirements" did not wait for that confirmation, to be started.
To collect and analyze all relevant specification documents and to gather the information on human and commercial factors involved in the implementation of 3-point shoulder harness on passengers aircraft seats (e.g. passenger’s size evolution), took more time than the 2 months initially planned.
Following completion of task 1, the PR01 report was eventually delivered on March 20th 2002.

The following task #2.1 "Design Definition", based on the results of the Dynasafe tests for structural design references, as well as the design requirements defined in task #1 for cabin installation interface, was started therefore with a 2-months delay.
A lot of efforts were spend to analyze the feasibility of introducing lighter materials.
For example, the use of titanium to replace components made in steel and injected reinforced polymers instead of aluminium was studied in detail with specialized industrials, mainly in Belgium and Holland for commodity reasons.
Meeting the specialized industrials, exploring alternate materials solutions and relevant production aspects was a time consuming process in order to select the most appropriate ones.
In addition to the structure optimization, quite a lot of effort was spend by AVIO to propose a general styling and comfort design definition.
Nevertheless, the next task # 2.2. "Design execution", started end June 2002 and was steadily progressing with the preparation of the detail design drawings of components.
Resulting from the above, the Progress Report ‘’PR02’’ covering the Design Definition task activity was merged with in the Detail Design Task report ‘’PR03’’.

Updated project plannings were regularly prepared and agreed by the partners, taking into account the demand for two months contract extension to mid-March 2003 adressed by the Co-ordinator to the EC.

The 2 months postponement has an impact on the Going-Safe project planning, delaying the end of the design optimization phase during the summer holiday period and therefore the overall other subsequent tasks as well.

7. Management and co-ordination aspects

7.1. Management aspects

- Co-ordination meetings

Several meetings were organized by the Co-ordinator during the project, to make the progress review of the work, to discuss open questions, to list and plan the required coming actions with the concerned partners.

Date of Meeting	Subject	Location	Place	Attendance
November 21st 2001	WP #1 First Working Session	SD&A	Brussels	F. BRAUN, SD&A, AVIO, TNO
January 22nd 2002	WP #1 Progress Review	TNO	Delft	F. BRAUN, SD&A, AVIO, TNO
March 21st 2002	WP #3.1 First Working Session	SD&A	Brussels	SD&A, TNO
May 8th 2002	WP #2.1 Critical Design Review	AVIO	Latina	SD&A, AVIO, TNO, F. BRAUN
June 21st 2002	Project Progress review with EC.	SD&A	Brussels	EC, SD&A
July 2nd 2002	WP #3.1 Progress Review	TNO	Delft	SD&A, TNO
July 9th 2002	Mid-Term Assessment Meeting	SD&A	Brussels	EC, SD&A, AVIO, TNO, F. BRAUN
August 28th 2002	WP #2.2 Critical Design Review	AVIO	Latina	SD&A, AVIO
October 17th 2002	WP #2.2 Critical Design Review	SD&A	Brussels	SD&A, AVIO, TNO, F. BRAUN
December 4th 2002	WP #2.2 Critical Design Review	AVIO	Latina	SD&A, AVIO
January 24th 2003	WP #3.2 Progress Review	SD&A	Brussels	SD&A, AVIO, F. BRAUN
February 3rd 2003	WP #3.2 Progress Review	AVIO	Latina	SD&A, AVIO
February 7th 2003	WP #3.1 Progress Review	SD&A	Brussels	SD&A, TNO, F. BRAUN

The minutes of each meeting were drafted by each Task responsible and sent to the Co-ordinator.

7.2. Contacts details

The Going-Safe Consortium has been composed by 4 partners, as listed here :

N° Contrator	Country	Name	Function
1	BE	SD&A s.a.	Prime Contractor – Coordinator Engineering of the seat structure
2	BE	F. BRAUN	Contractor – Seat design Expert Exploitation Manager
3	IT	AVIOINTERIORS	Contractor – Styling and Upholstery design / Seat equipments / Cost Benefit Analysis
4	NL	TNO Automotive	Contractor – Dynamic simulation / Safety automotive technology expert

Partners Co-ordinates

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8. Results and Conclusions

We can state that the *Going-Safe* seat :

- has slightly higher production costs ;
- has higher maintenance costs because of its specific features;
- even if installed as Front Row Seat only, represents a higher operating cost for the airline;
- in this case due to the different belt system with the rest of the cabin, the FRS passengers could think that they are sitting in a more dangerous location (this is a sensitive issue for airlines) ;
- requires a revised crew training for specific cabin safety instructions;
- requires different safety announcements, through video and written instructions as applicable;
- cannot be installed as a mean to increase the cabin seating capacity because the saved space onboard is not enough to install further rows of seats.

but :

- in case of installation as Front Row Seat only in a wide-body aircraft, conntributes to an average weight saving of 378 kg per aircraft, corresponding to a saving of 34 tons of fuel per aircraft per year (assuming an average operation of 3000 flying hours per year);
- the above payload increase corresponds roughly to a value 180,000-230,000 $ per aircraft per year.

The Going Safe concept has been initially foreseen for a complete aircraft layout.

Today the Going Safe seat seems to be strictly required for Front Row Economy only and of aircrafts only, which are requiring actually full dynamic certification compliance for passenger seats : **A340-500/-600 and B777.**

This situation limits the market for the Going Safe seat to 10% only of the total seats in the economy class.

So we have to assume a production limited to a batch of about **1000 pax per year.**

Nowadays there is not any mandatory regulation issued by the Airworthiness Authorities requiring the change of the actual passenger belt system in a compulsory way.

It is true that the rules are intended as minimum requirements only and their implementation by operators is always possible, but the airline market is regulated by stringent economic rules, specially in a very critic environment like at present days, so it is highly improbable to find an airline available to invest in such an innovative project.

In case of new regulations requiring the compulsory use of 3-PSH's, as for other cases in the past, the Authority would require a system capable to be retrofitted on existing seats, otherwise the economic impact on operators would be too heavy.

For the future, all the new aircraft will be considered by the regulation and a possible retrofit possibly very slowly, that is on a period of more than 10 years from now. A Going Safe seat for Front Rows seems to be a positive solution issues, and furthermore for the benefit to save few inches in front of the monuments onboard, thanks to its capability to avoid the passenger's head impact against bulkheads.

Therefore first step is to consider the Front Row installation only and second step the entire cabin, when the market economy will return positive.

Different is the case of the aircraft manufacturers, specially in case of new aircraft models launch, like the A380 for Airbus.

The aircraft manufacturers are generally available to invest in supporting new proposals bringing the frontiers of the public air transportation safety another step forward.

We are sure to having worked in this direction.

9. Acknowledgements

SD&A Company, Project Co-ordinator, on behalf of all the Going-Safe Contractors, would like to thank the EUROPEAN COMMISSION - DG VII for their support and their contribution to this Transport RTD programme, and in particular Mr. Christopher North, the EC. Scientific Officer in charge of this Going-Safe Program.

The project Co-ordinator is pleased to have collaborated during this 16 months project duration with all the partners of the Going-Safe consortium : AVIOINTERIORS S.p.A. (Italy), TNO Automotive (The Netherlands), and François BRAUN.
The co-operation between companies from different European countries was of the highest interest on technical and human relations aspects.

In particular, SD&A would like to thank Mr. François BRAUN for the preparation of the program proposal.

10. References

This document contains information from :

- **Going-Safe Progress Report P.R.01 – Workpackage WP #1 Design Requirements, 20/03/02**

- **Going-Safe Progress Report P.R.02 & 03 – Workpackage WP #2 Design defintion and execution, 14/02/03**

- **Going-Safe Progress Report P.R.04 – Workpackage WP #3 Technical & Economical Assessment, 21/02/03**