



JSF HMDS

Author: Bob Foote

JSF HMD Technical Lead

Technical lead for all major fixed wing HMD programs at Rockwell Collins since 1995. Programs include VCATS, JHMCS and JSF.

Author: Simon Smith

Technical Director at Helmet Integrated Systems Limited involved in all aspects of the companies R&D department since 1978.

The Joint Strike Fighter, the JSF, is being developed by Lockheed Martin Aeronautics Company for the US Air Force, Navy and Marine Corps and the UK Royal Navy. The stealthy, supersonic multi-role fighter is to be designated the F-35.

Vision Systems International, L.L.C., a joint venture between Rockwell Collins and EFW Inc./Elbit Systems Ltd., will provide this HMCS featuring day and night targeting capability and a wide field of view enhancing the pilot's situational awareness.



JSF HMD November 2003 Flight Demonstration

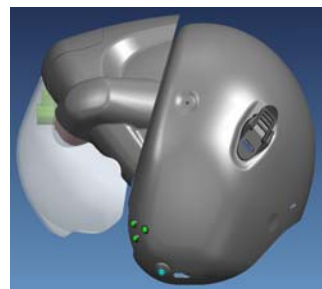
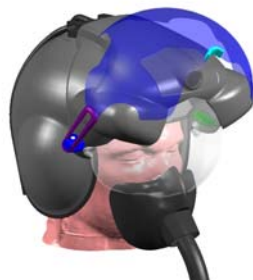
VSI subcontracted the design and development of the helmet assembly unit, HAU to Helmet Integrated Systems Ltd who have a history dating back to 1924 with the principal activity of design, testing, manufacture and marketing of protective helmets and communications equipment.

The JSF HMD development story began with the IRAD concept demonstrator. The Next Generation Demonstration Helmet Mounted Display provided evidence that a wide field of view, light system could be developed and mass produced to the stringent requirements of the JSF program. Several advances were required to make this possible:



- A solid optical platform that is lightweight and accurate
- Rigid structure that is ejection safe
- Day and night display capabilities

To achieve these goals the JSF team made advances a optical structural design that meets the accuracy and wide field of view requirements.



Concept Demonstrator thru to initial flight demonstration

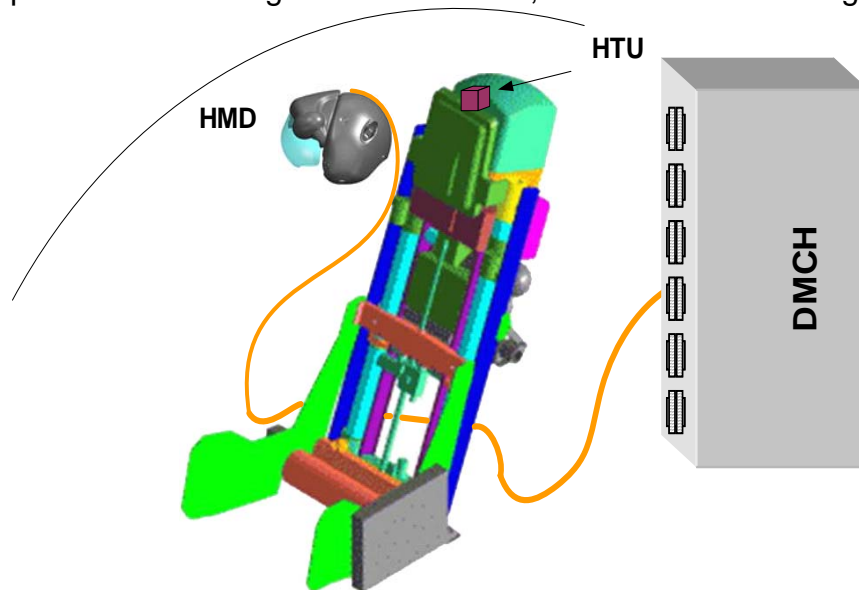
After award of the Helmet Assembly Unit, HAU, contract in November 2002 a joint design team instigated a CAD based development programme to integrate the Helmet Display Unit, HDU onto the HAU. This design strategy allowed rapid prototyping of the initial design models resulting in the first tooled hardware models being presented for pilot assessment in April 2003 and a successful round of centrifuge testing and initial windblast tests conducted from June to August of that year.

A number of design challenges had to be met through the design phases to meet the stringent mass control programme, material assessments and development of a specialised fitting system.

HMD Overview

The HMDS is a helmet mounted aiming system, which provides a "Head Out" display, virtual HUD capabilities and Aircraft (A/C) weapons and sensors aiming capability based on pilot Line Of Sight.

The HMDS comprises the following main assemblies, as described in the figure below:



JSF HMDS Block Diagram

Helmet Mounted Display (HMD)

The HMD provides binocular high resolution displays to the pilot (L-HDU, R-HDU) and hosts the Adaptive Magnetic Receiver Unit (AMRU) and day/night camera. The HMD is connected to the DMC/H through the Helmet Vehicle Interface (HVI). The HMD is comprised of three assemblies:

- 1) Helmet Assembly Unit (HAU): This assembly includes the helmet shell, fit system, and active noise reduction (ANR).
- 2) Helmet Display Unit (HDU) This assembly attaches to the top of the HAU and contains the display optics, AMRU, helmet camera and the display visor. All of the items are rigidly held in place by a light weight composite binocular, optical support structure (BOSS).
- 3) Helmet Vehicle Interface (HVI): This assembly connects the HMD to the ejection seat via a quick disconnect connector (QDC).

Display Management Computer / Helmet (DMC/H)

The DMC/H controls all HMDS elements and is installed in the JSF aircraft. It interfaces to aircraft via high speed fiber channels. The DMC/H is equipped with the following Printed Wire Assemblies (PWAs):

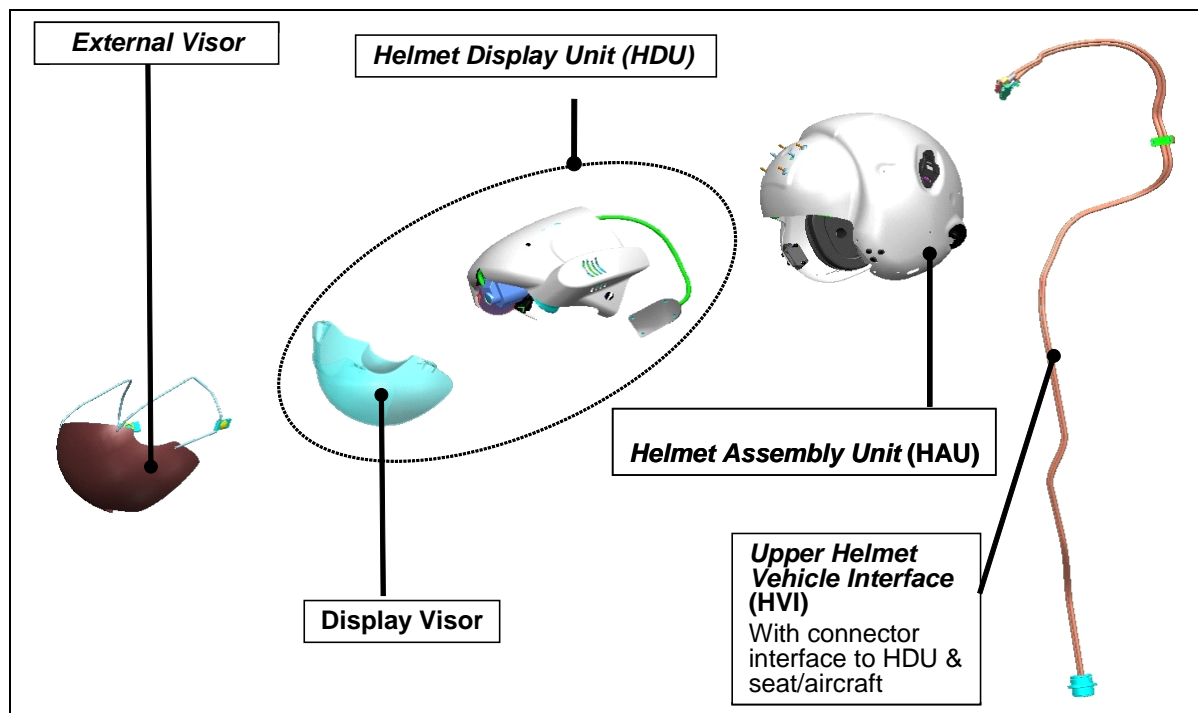
- 1) Hybrid tracker Line Of Sight / Image Correlation (LOS/IC) PWA – The LOS/IC is responsible of acquiring pilot line of sight managing the tracker h/w and controlling the cameras.
- 2) Display Processor (DP) - The DP generates displays to be projected to the pilot and for debriefing.
- 3) Low Voltage Power Supply (LVPS) - providing power to all HMDS components.

Helmet Transmitter Unit (HTU)

The hybrid tracker is consisted of Hybrid Transmitter Unit (HTU) and Adaptive Magnet Receiver Unit (AMRU). The HTU is firmly mounted to the cockpit and generates magnetic field within the cockpit. The magnetic field is sampled by the AMRU (located in the HMD). The samples are used in order to resolve the pilot line of sight (LOS).

HMD Components

The HMD consists of four major components as depicted in the figure below:



Feature of the HMD are listed in the following table:

Parameter	Characteristic
Weight	3.5 pounds
Anthropometric Range	1 to 99% of JSF pilot community
Ejection Safe	Safe to 600 KEAS Ejection
Comfort and Fit	6 hour minimum flight time

Upper Helmet Vehicle Interface

The Upper HVI is the cabling that provides the electrical interface to the HMD from the Display Management Computer/Helmet (DMC/H). The Upper HVI is connected to the lower HVI that is part of the Aircraft wiring. The point of connection between the upper and lower HVI is the Quick Disconnect that separates the equipment from the aircraft during ejection.



Helmet Assembly Unit

The Helmet Assembly Unit (HAU) provides both the protection function for the pilot and platform for the display. The HAU has been designed to meet the large anthropometric range required by the JSF pilot community.

Helmet Display Unit

The Helmet Display Unit (HDU) provides the pilot with the wide field of view display as well facial protection during ejection. The HDU assembly includes the Display Visor that the image to the pilot is displayed. The Display Visor also provides the full facial protection as required by MIL-V-43511. It has been proven to meet impact and ballistic requirements. The HDU in combination with the Display Visor meets a high degree of accuracy that allows the unit to replace the Heads Up Display. Some of the characteristics of the display are listed in the table below:

Parameter	Characteristic
Field of View	30° X 50°
Accuracy	Less than 2 mr RMS
Contrast	> 1.2 at 10,000 Ft L
Resolution	1280 X 1024

Along with the display characteristics the HDU includes a Day/Night camera that provides full flight coverage. The camera has been designed to meet the full range of brightness of a typical day camera as well as typical NVGs.

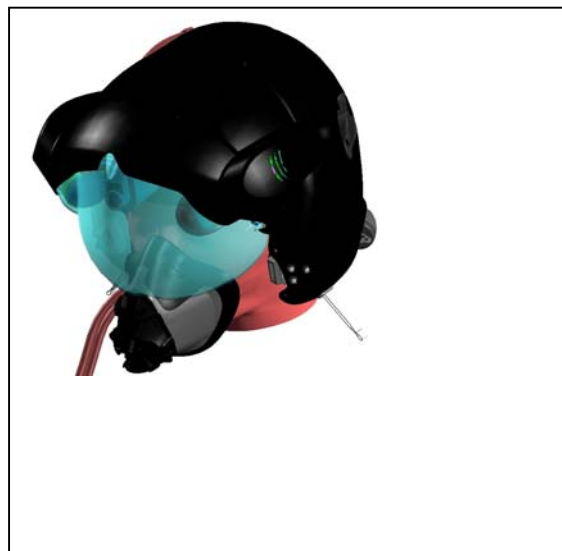
External Visor

The External Visor provides the pilot the capability of changing the see through transmission based on the external ambient lighting conditions. The External Visor is designed to be low cost and lightweight. The External Visor is available in many shades required to meet any particular mission.

HMD Physical Characteristics

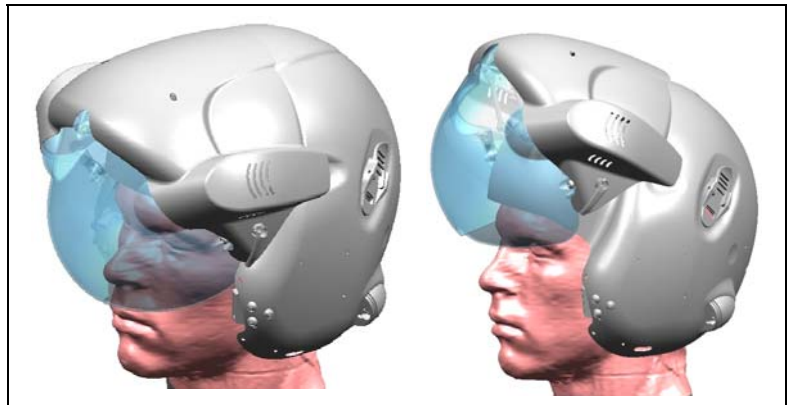
The HMD requirements included the most aggressive weight and CG requirements to date. The HMD weighs only 3.5 pounds but has a full binocular capability and meets all of the JSF requirements listed below:

- Safety
- Accuracy
- Weight
- Centre of Gravity
- Impact and Penetration
- Ballistics
- Brightness
- Full Day/Night operation

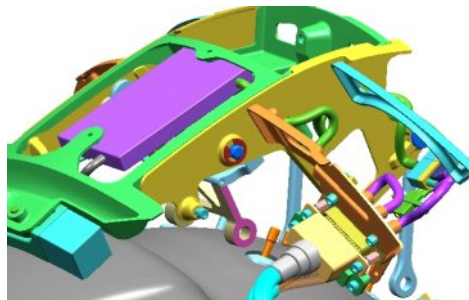


HMD Visor operation

The display visor is a fixed integral part of the HDU, module and hence donning and doffing of the HAU and the need to lift the visor during use raised new challenges. To overcome this, the design team developed an articulation system that allows the complete HMD to be retracted clear of the wearers face.



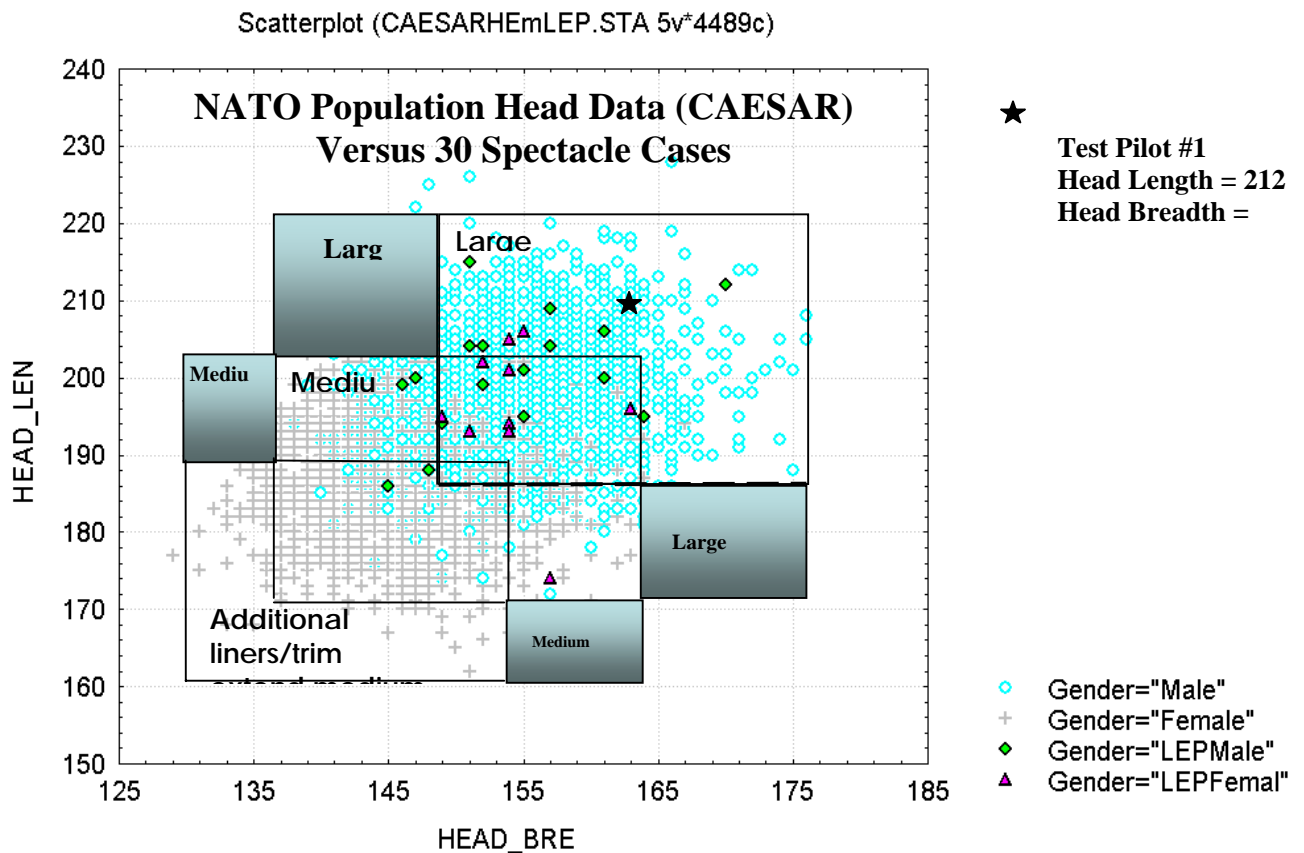
The main advantage of pursuing this route was to maintain close control of the optical interfaces thus optimising the system performance. However this created a significant design challenge in developing a light weight structure capable of supporting the HDU throughout its travel whilst retaining sufficient strength to meet the challenge of a 600 knot windblast.



HMD Articulation

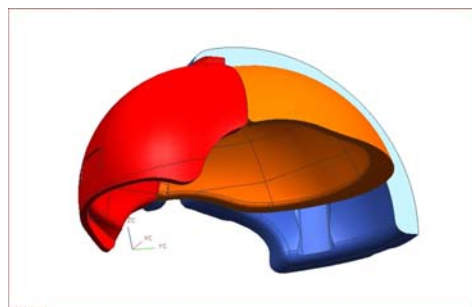
HMD Mechanical Layout

The anthropometric range required for the JSF HMD has been derived from the CAESARH data base and two meet this two shell sizes of HAU, designated medium and large, have been developed which link to a single size HDU. Current evaluations indicate that there is a need to generate to different trim profiles of the medium shell primarily to narrow the aperture when worn by subjects at the lower end of the percentile range. This in effect creates a small size which offers benefits on ejection to the small subject base.



CAESARH Scatterplot

The HAU comprises a fixed primary impact attenuating liner with a secondary customised liner providing the stability and control of fit. Development of the nape pad and headset tensioning systems were derived from the already proven ALPHA helmet range.

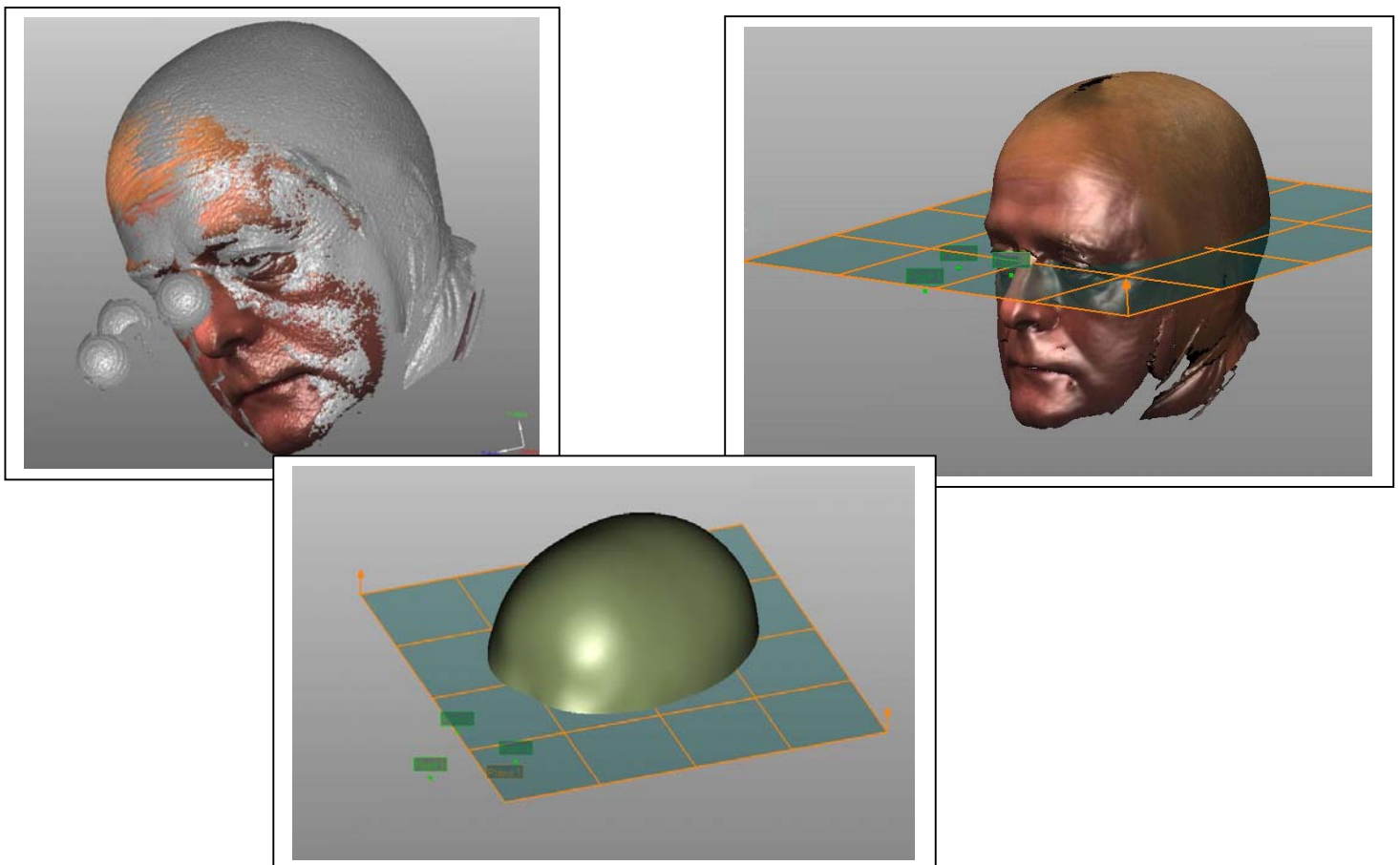


Primary impact and customised liners

Initial HAU development employed semi-rigid crown pads to maintain HDU/HAU attitude. However man rating assessments were prioritised to examine the frontal liner fit, comfort and stability issues and the generic design of pads was found unsatisfactory.

A programme was instigated to look at developing a customised liner approach. A number of scanning techniques have been employed to capture head and body data. Initial head size data was provided by WPAFB but the scanning techniques used tended to leave the top of the head undefined. It was identified that this area was critical to correct fit and stability of the HMD and hence scanning systems were revisited.

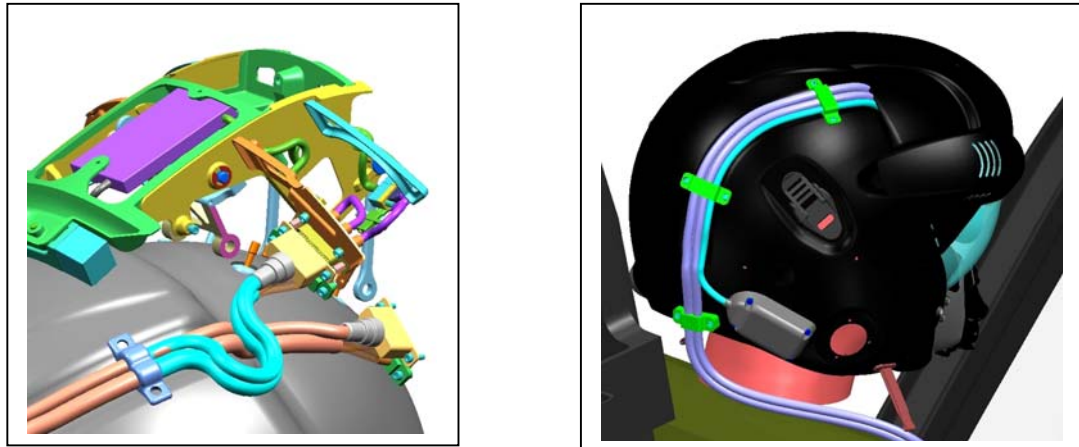
A Minolta system was employed as the base scanning unit as it was fully developed, portable and easily transportable. An optical alignment system and support chair were developed which allowed the whole head (including the crown) to be scanned. Subsequent processing of the data allowed the cranium to be defined and a representation to be machined directly into an EPS billet.



Head Scanning

Helmet Vehicle Interface, HVI.

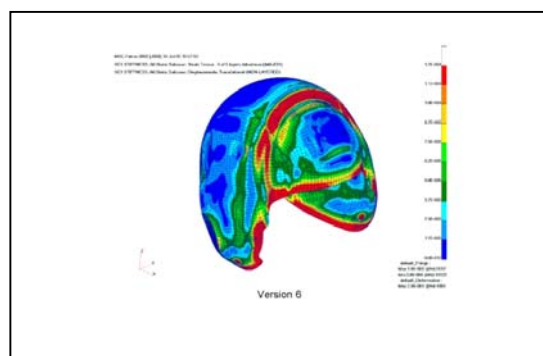
A major part of any HMD programme is interfacing the HDU to the aircraft. Cabling and cable routing around the man and the aircraft cockpit provide interesting integration issues. This work is ongoing but HDU and HAU assessments have been undertaken to design a system that is robust enough and yet allows full manoeuvrability of the HMD and functionality of the separate units i.e. HDU articulation.



HVI Routing

FEA

The CAD models were used in a FEA investigation into impact modelling which in turn was used to develop the lay-up for the HAU. During this phase of the programme a change was instigated to increase the impact performance requirements and to fully define the impact zones. Two primary areas were defined one encompassing the rear of the helmet in an area likely to come into contact with the ejection seat head box and the second area covering the remaining surface of the helmet.



Typical FEA plot

With regards to the rear impact site, liaison with and testing at Martin Baker was carried out on the proposed JSF seat head box design to assess the system effects. The HAU was also tested separately using conventional impact test apparatus. Two impact levels were determined, 6.5ms^{-1} for the rear impact zone and 6.0ms^{-1} for the all other areas. The first phase testing looked at the HAU as an independent unit however the test apparatus

was weighted so that the test mass was representative of the anticipated full system weight.

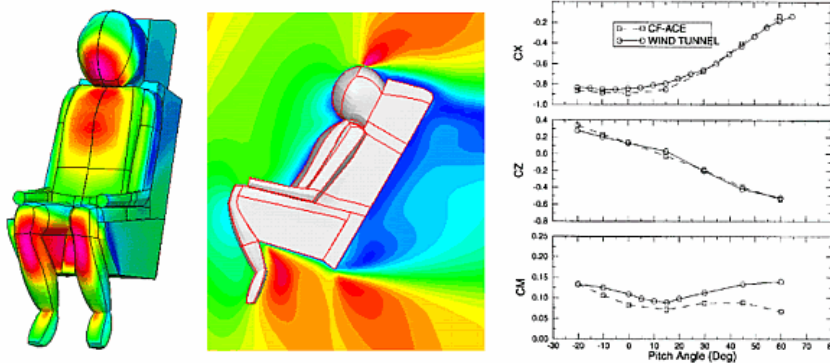
This system estimation was to include the test head form, the HAU, the HDU and the oxygen mask. An over allowance was made for ancillary (as yet undefined) equipment. Therefore the total system mass (including test headform) subjected to impact testing was 7.2kg which gave an impact energy at the rear of 152 Joules and for other areas 130 Joules. Tests were carried out under conditioning at +50°C, -20°C and at ambient (room) temperature. All test results were well within the allowable range of 300g.

CFD results Validation

The HMDS design team has done a full complement of Conformal Fluid Dynamic (CFD) analysis as a key tool in the HMD development. Prior to any testing such as windblasting a CDF analysis was completed. The results of the analysis showed that the HMD could and would meet all head and neck loading requirements. The CFD analysis were confirmed by a separate team where very similar results were obtained.



Windblast Setup



HMD CFD Analysis

The design is now entering the next phase of evaluation and test.

End.