REACTION ENGINES

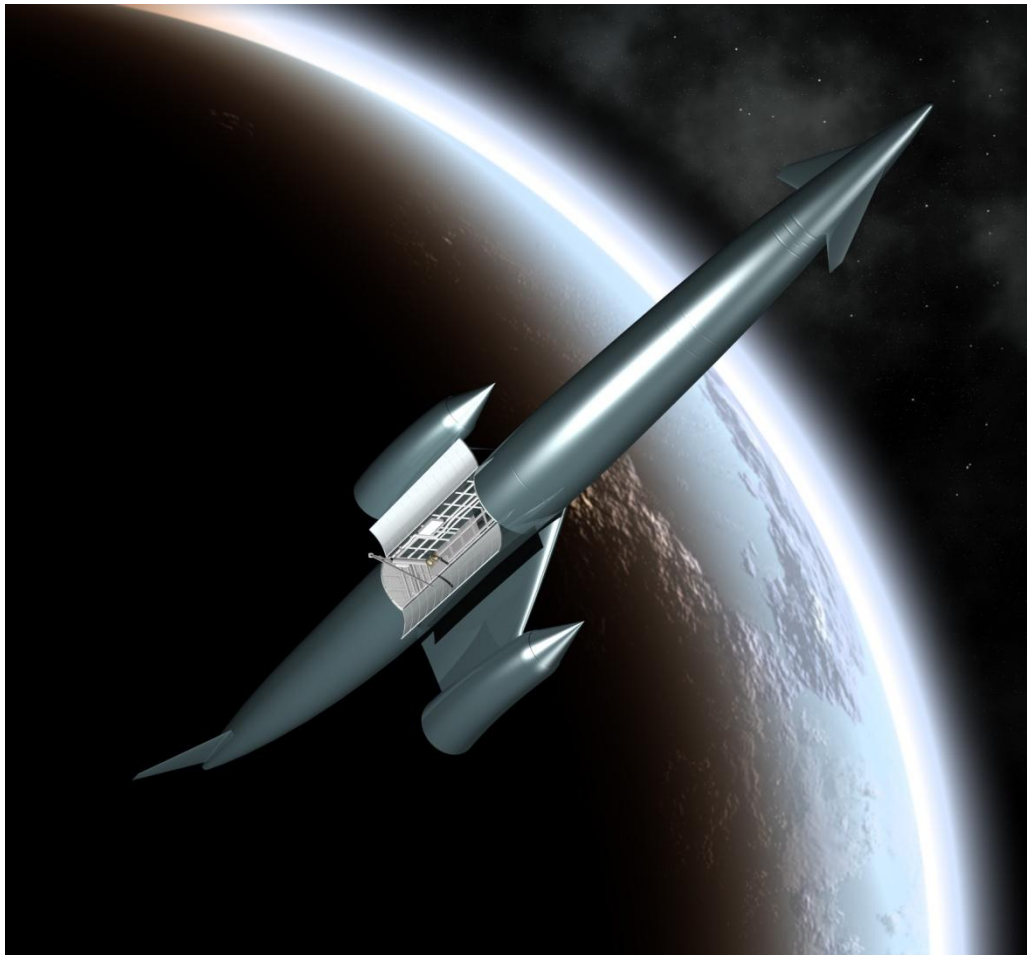
Progress
on the
SKYLON Reusable Spaceplane

7th Appleton Space Conference
8 December 2011

Alan Bond
Managing Director

REACTION ENGINES

SKYLON C1



12 tonnes to LEO

10 tonnes to ISS

200m^3 payload bay

4.6m diameter payload

Being revised to D1
Payload 15 tonnes to LEO

REACTION ENGINES

Company Structure (April 2011)

Headquarters

Design and Test Facilities

Culham Science Centre

Experimental production

Abingdon

Sheet metalwork & fabrication

Wantage

Precision engineering

Newbury

REACTION ENGINES

Progress on SABRE

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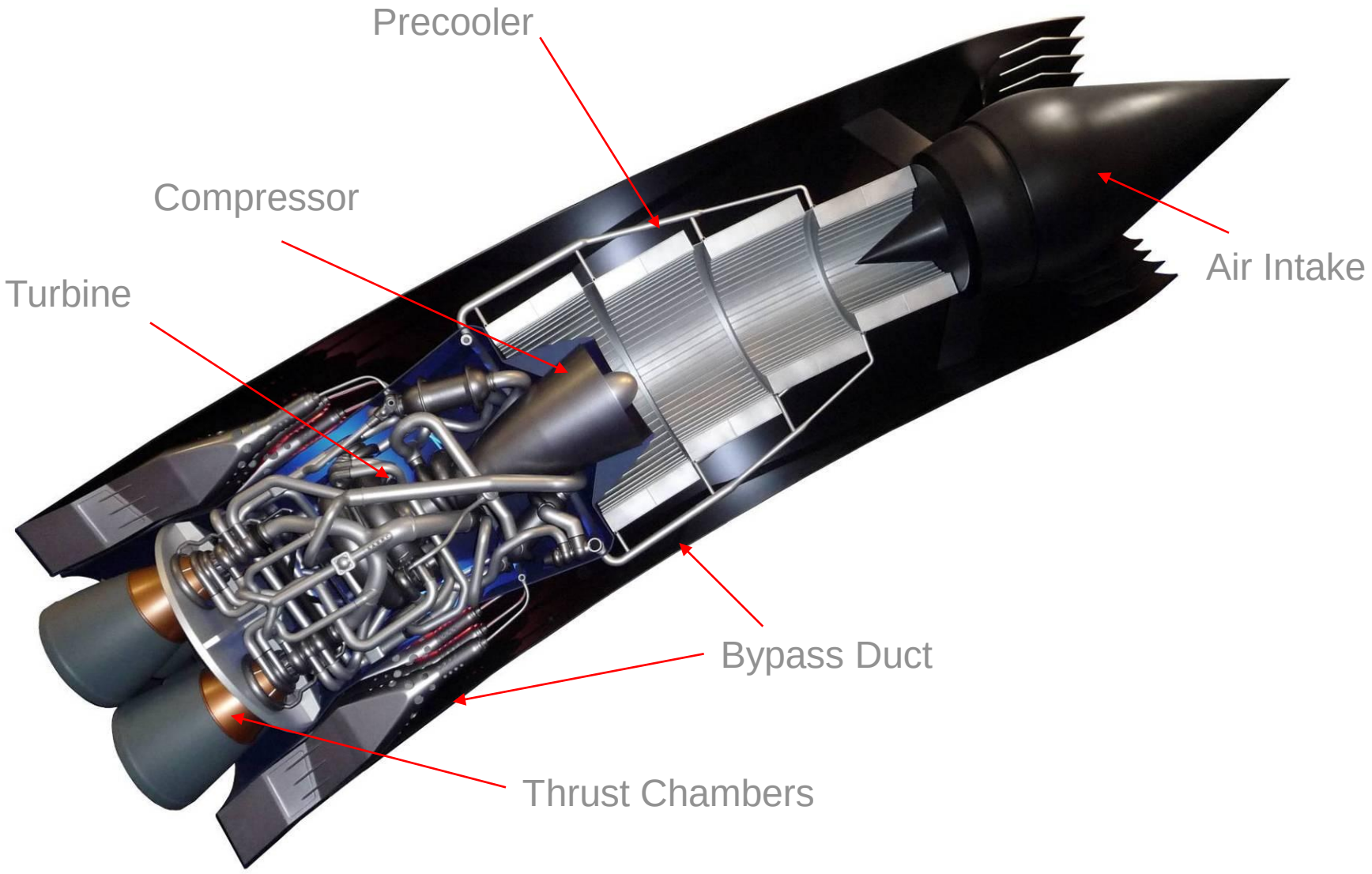
SABRE-3 Engine



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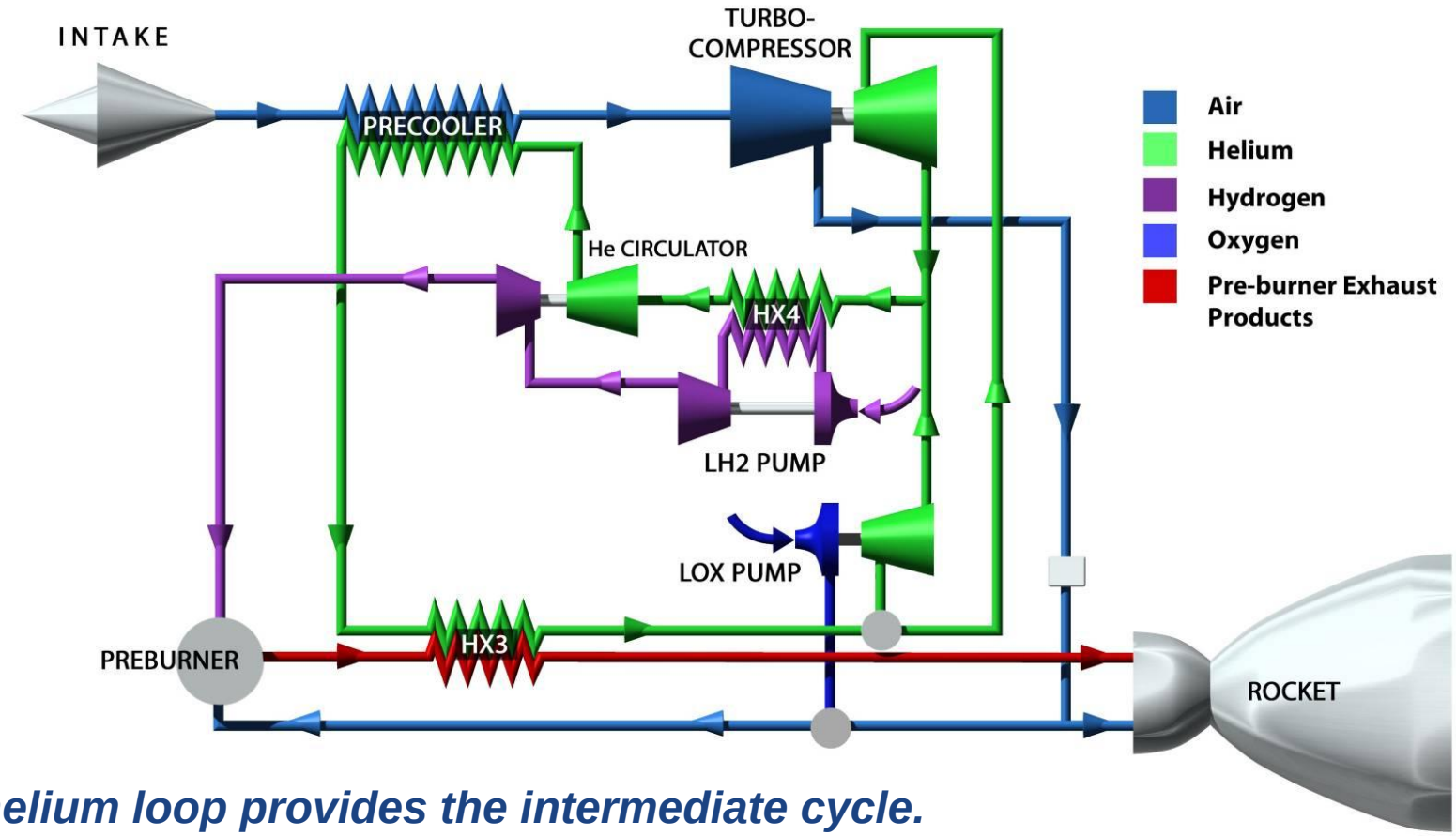
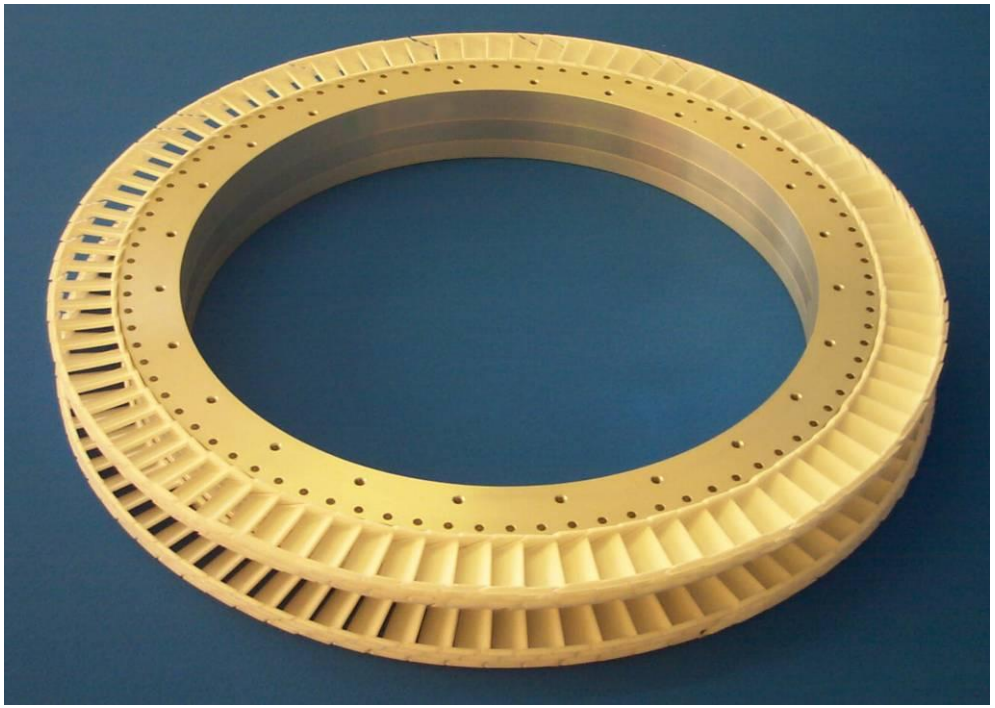
The SABRE Engine Cycle



A helium loop provides the intermediate cycle.

In rocket mode LOX replaces the air fed to the combustion chamber.

Inlet Plenum & IGV Assembly



Rotors 1 & 3

Rotors 2 & 4

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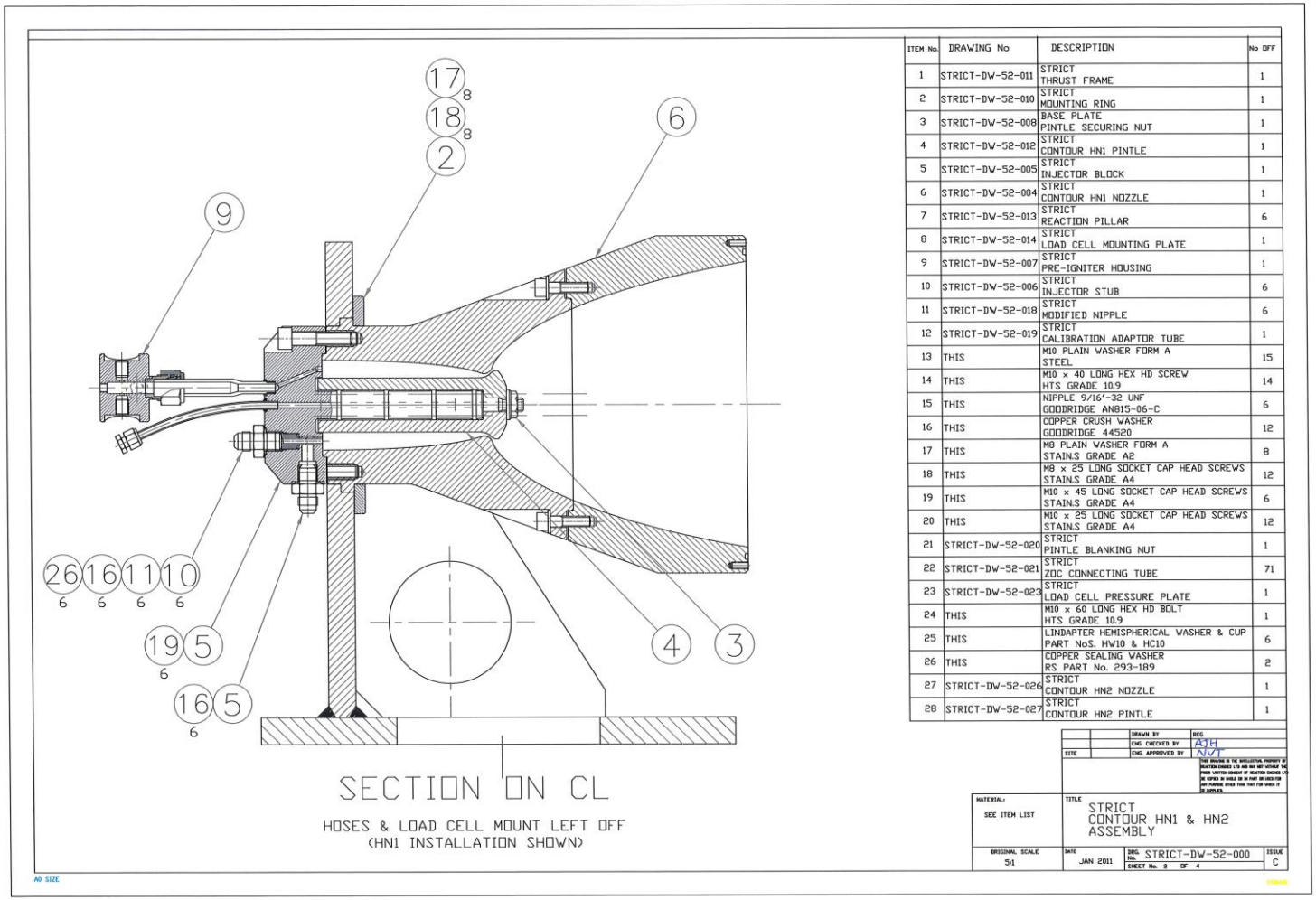
Experimental Contra-rotating Stator-less Turbine Installation

REACTION ENGINES

STRICT Thrust Chamber



ITEM No.	DRAWING No	DESCRIPTION	No OFF
1	STRICT-DW-52-011	STRICT THRUST FRAME	1
2	STRICT-DW-52-010	STRICT MOUNTING RING	1
3	STRICT-DW-52-008	BASE PLATE PINTLE SECURING NUT	1
4	STRICT-DW-52-012	STRICT CONTOUR HN1 PINTLE	1
5	STRICT-DW-52-005	STRICT INJECTOR BLOCK	1
6	STRICT-DW-52-004	STRICT CONTOUR HN1 NOZZLE	1
7	STRICT-DW-52-013	STRICT REACTION PILLAR	6
8	STRICT-DW-52-014	STRICT LOAD CELL MOUNTING PLATE	1
9	STRICT-DW-52-007	STRICT PRE-IGNITER HOUSING	1
10	STRICT-DW-52-006	STRICT INJECTOR STUB	6
11	STRICT-DW-52-018	STRICT MODIFIED NIPPLE	6
12	STRICT-DW-52-019	STRICT CALIBRATION ADAPTOR TUBE	1
13	THIS	M10 PLAIN WASHER FORM A STEEL	15
14	THIS	M10 x 40 LONG HEX HD SCREW HTS GRADE 10.9	14
15	THIS	NIPPLE 9/16"-32 UNF GOODRIDGE AN815-06-C	6
16	THIS	COPPER CRUSH WASHER GOODRIDGE 44520	12
17	THIS	M8 PLAIN WASHER FORM A STAINLESS GRADE A2	8
18	THIS	M8 x 25 LONG SOCKET CAP HEAD SCREWS STAINLESS GRADE A4	12
19	THIS	M10 x 45 LONG SOCKET CAP HEAD SCREWS STAINLESS GRADE A4	6
20	THIS	M10 x 25 LONG SOCKET CAP HEAD SCREWS STAINLESS GRADE A4	12
21	STRICT-DW-52-020	STRICT PINTLE BLANKING NUT	1
22	STRICT-DW-52-021	STRICT ZDC CONNECTING TUBE	71
23	STRICT-DW-52-023	STRICT LOAD CELL PRESSURE PLATE	1
24	THIS	M10 x 60 LONG HEX HD BOLT HTS GRADE 10.9	1
25	THIS	LINDAPTER HEMISPHERICAL WASHER & CUP PART NoS. HW10 & HC10	6
26	THIS	COPPER SEALING WASHER RS PART No. 293-189	2
27	STRICT-DW-52-026	STRICT CONTOUR HN2 NOZZLE	1
28	STRICT-DW-52-027	STRICT CONTOUR HN2 PINTLE	1

DRAWN BY RCG
ENG. CHECKED BY AJH
ENG. APPROVED BY NJT

MATERIAL: SEE ITEM LIST

TITLE: STRICT CONTOUR HN1 & HN2 ASSEMBLY

ORIGINAL SCALE 1:1
DATE JAN 2011
DRG. No. STRICT-DW-52-000
SHEET No. 2 OF 4
ISSUE C

A0 SIZE

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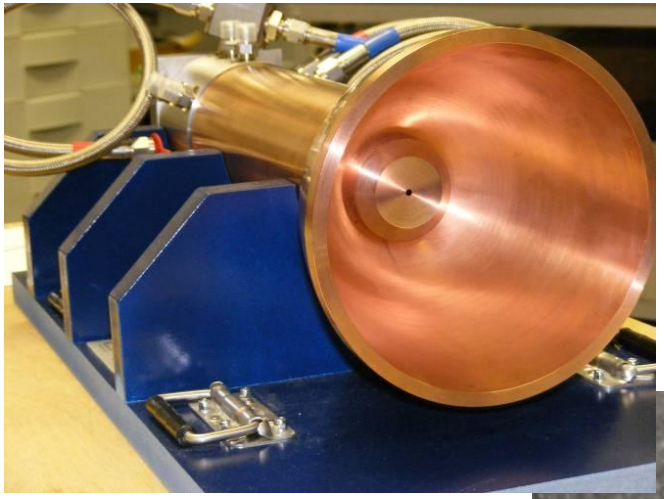
E-D Nozzle Test Program (STERN)

(Joint program Uni. of Bristol and Airborne Engineering)



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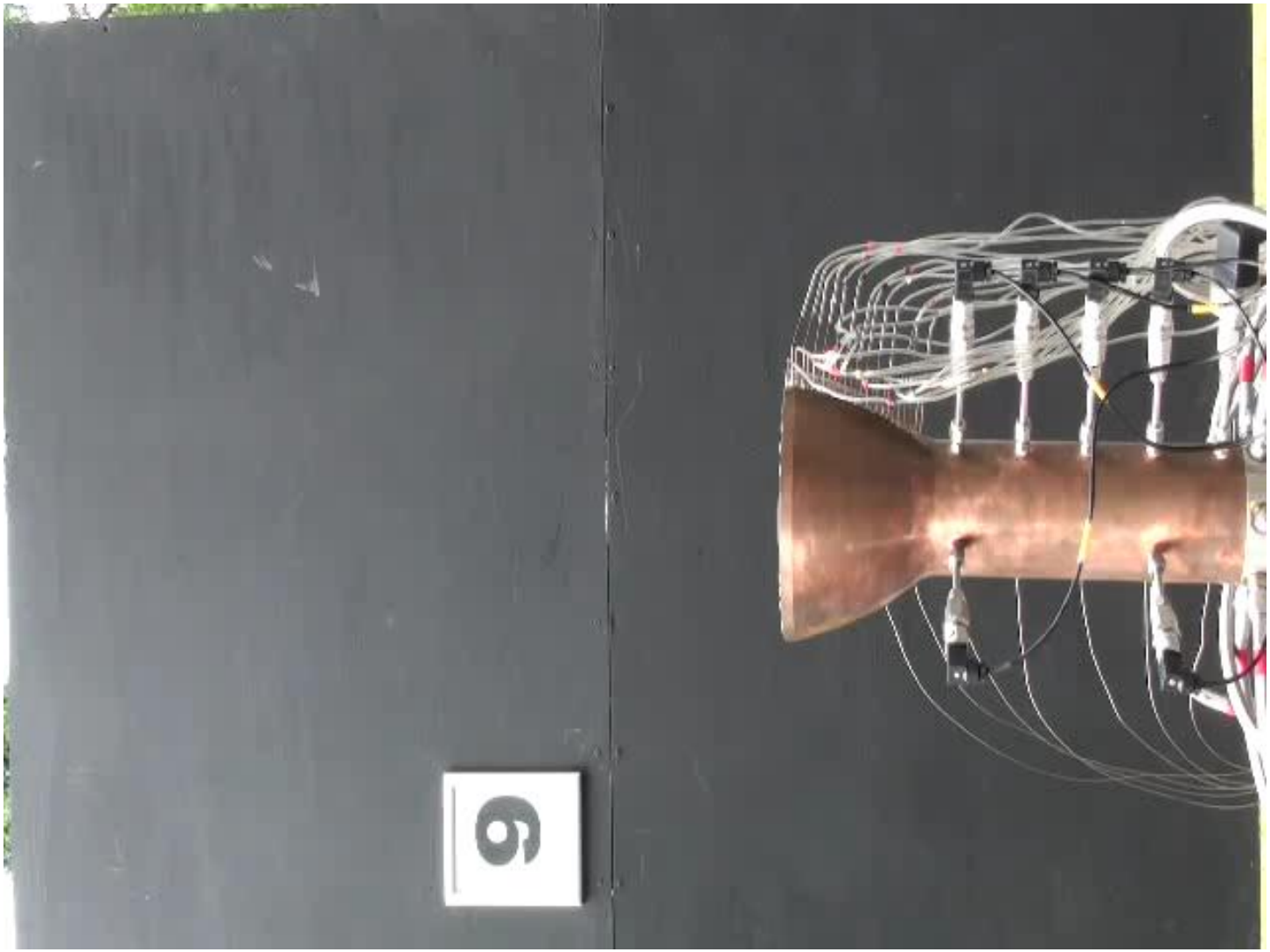
STERN Thrust Chamber Firing



REACTION ENGINES

Reaction Engines Testing

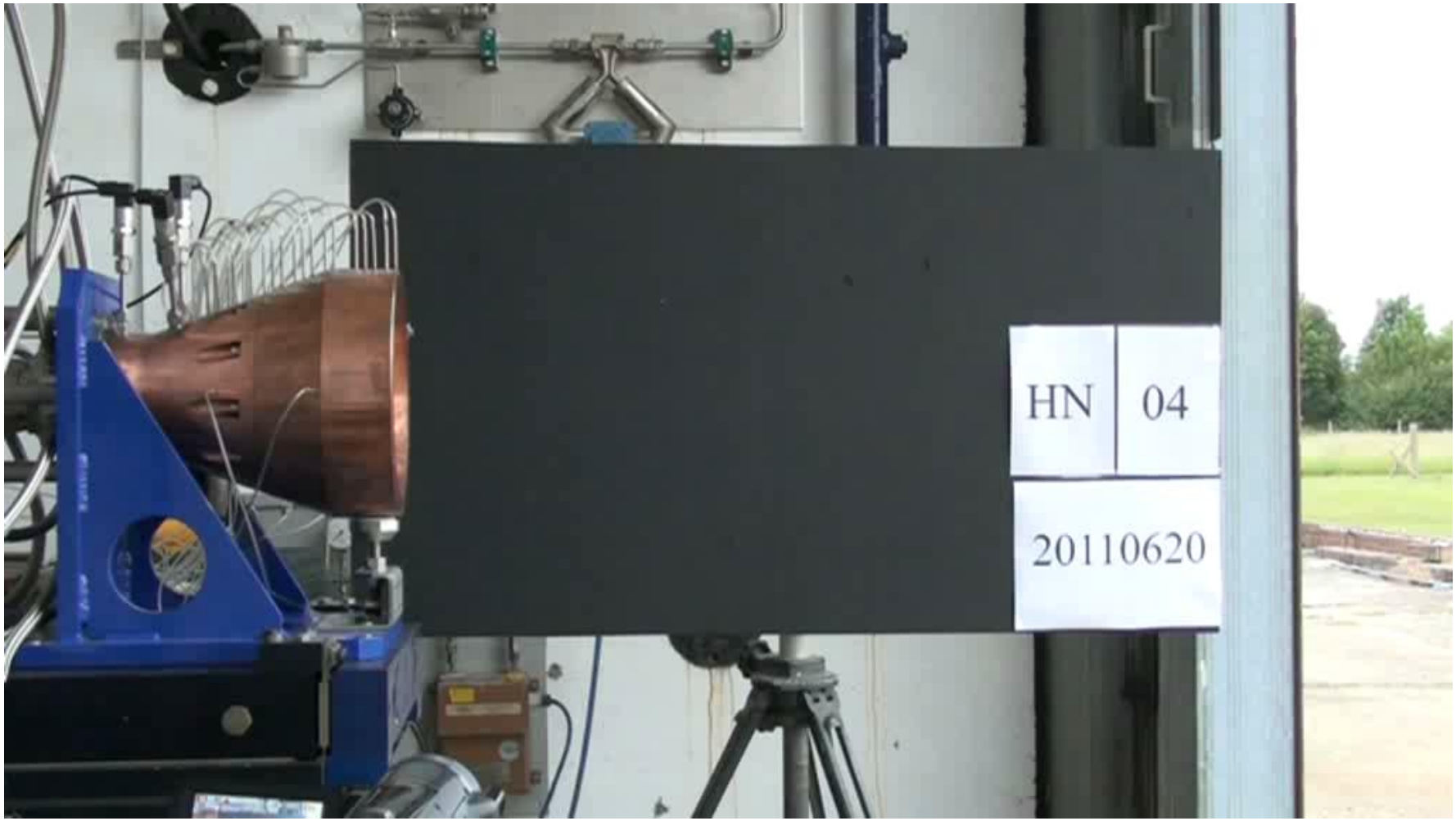
J-site at Westcott

Joint programme with Airborne Engineering

Thrust stand for Low-NOx and Strict Programmes

REACTION ENGINES

Strict Engine Test Firing – June 2011



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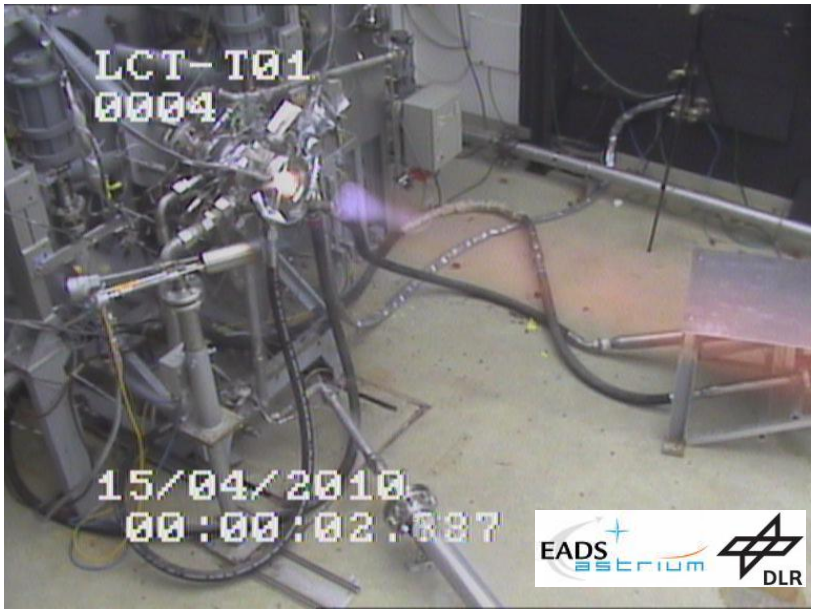
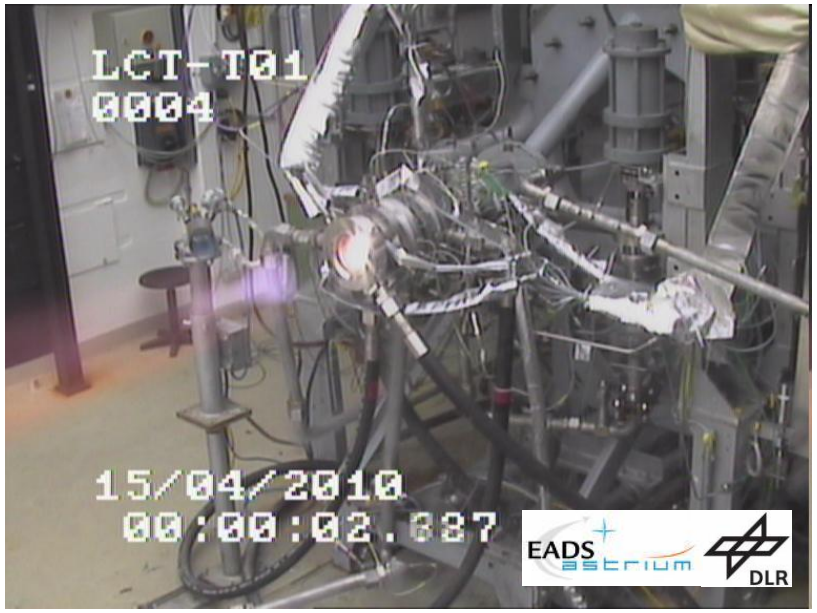
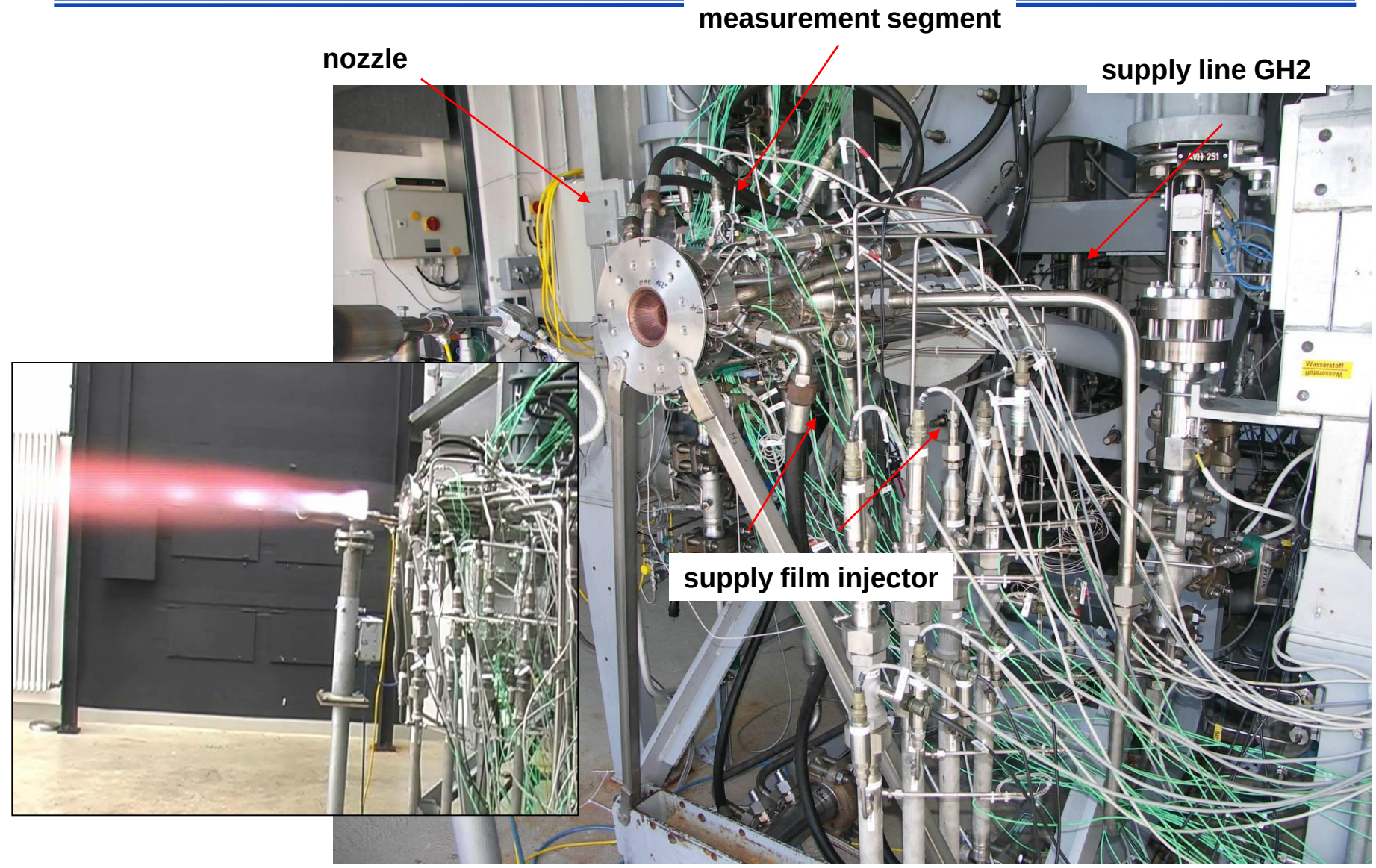
Test LCT-T01-4 @ pc=70 bar 8kg/s LOX cooling
Test bench P8, Lampoldshausen Germany





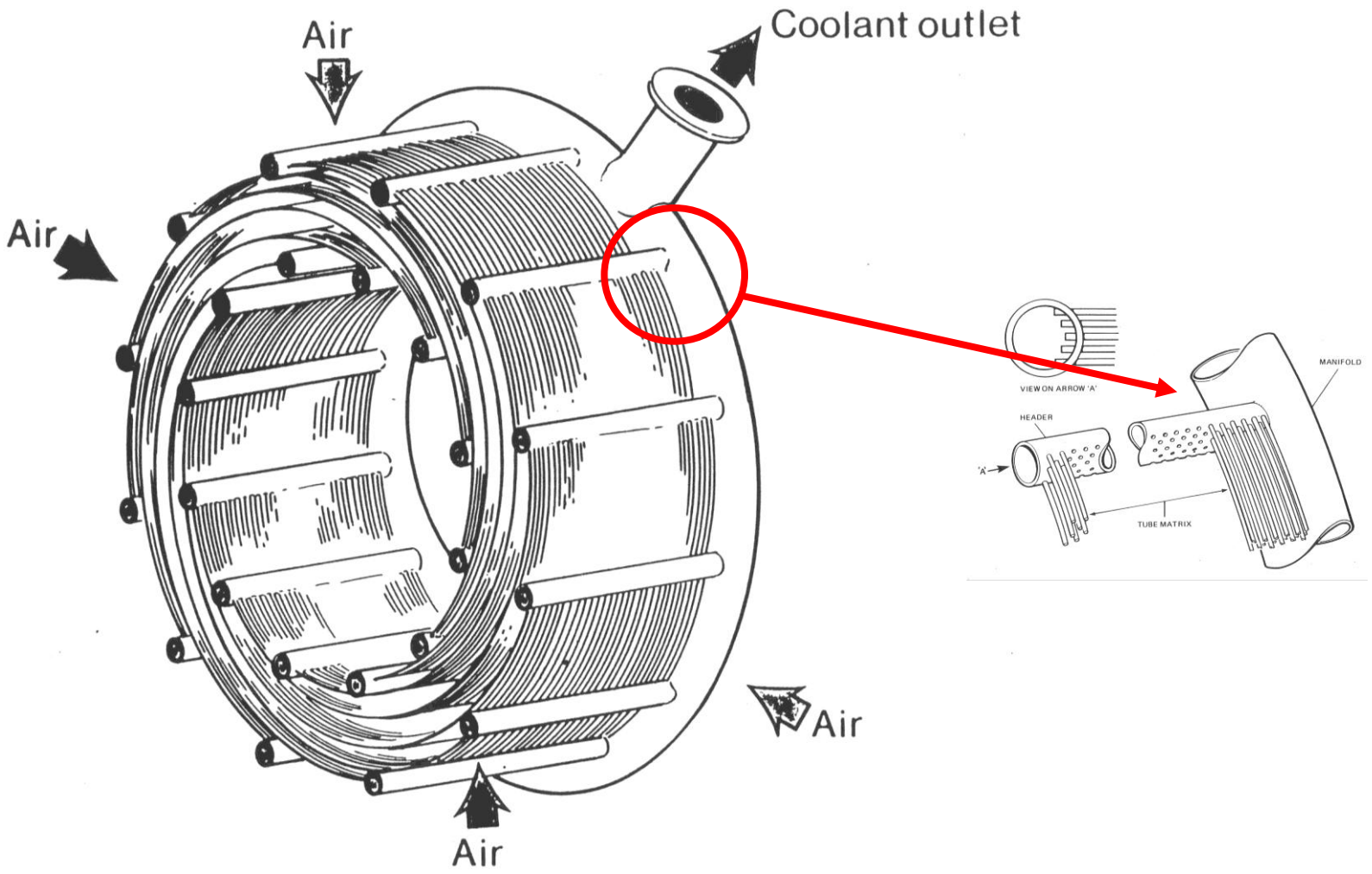
REACTION ENGINES

DLR Film Cooling Test Facility at P8 Lampoldshausen



REACTION ENGINES

Precooler Geometry



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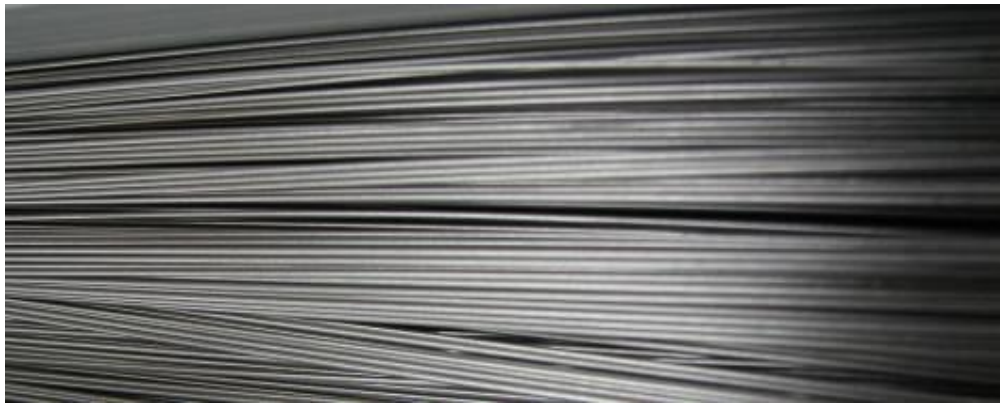
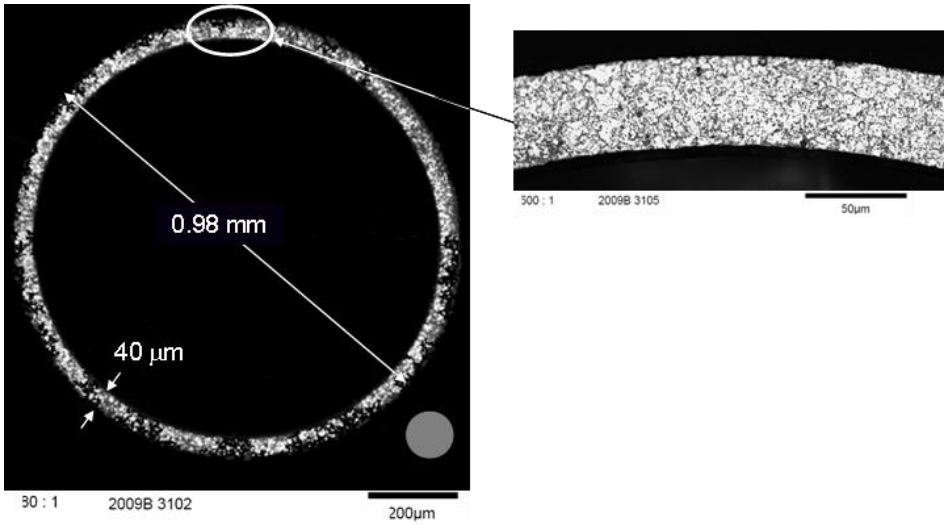
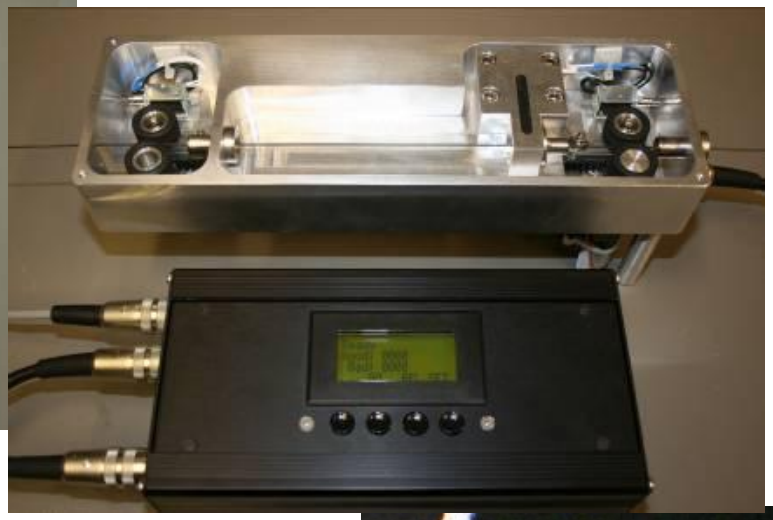
Matrix Production

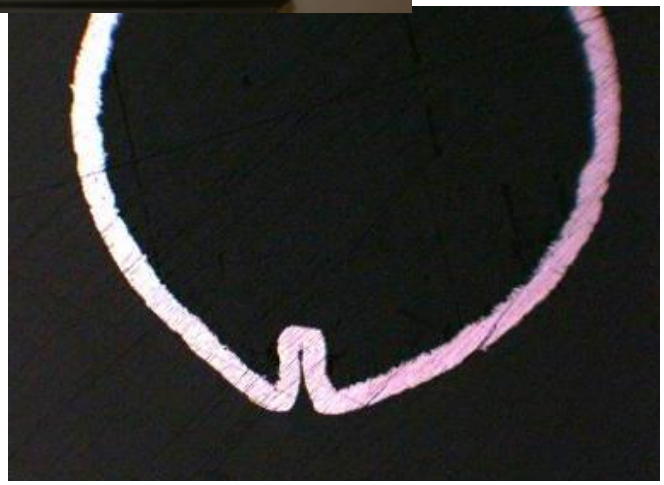


- The prototype pre-cooler will be made from over 16,000 thin-walled Inconel tubes.



Reaction Engines' Radley Road (Abingdon) Facility





- All incoming tubes are inspected and processed prior to module assembly.

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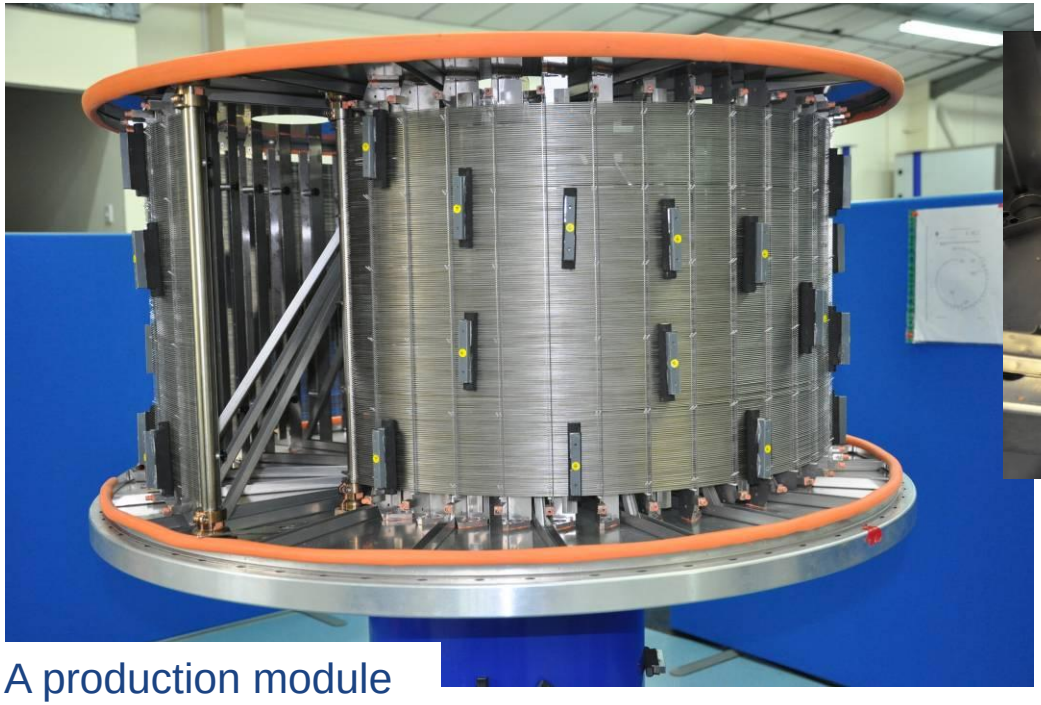
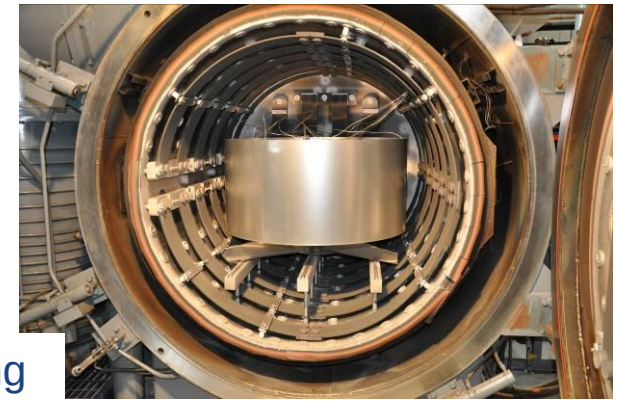
Pre-Cooler Construction



A production module under construction

Header tube installation

Header/matrix tube brazed joints



Vacuum brazing

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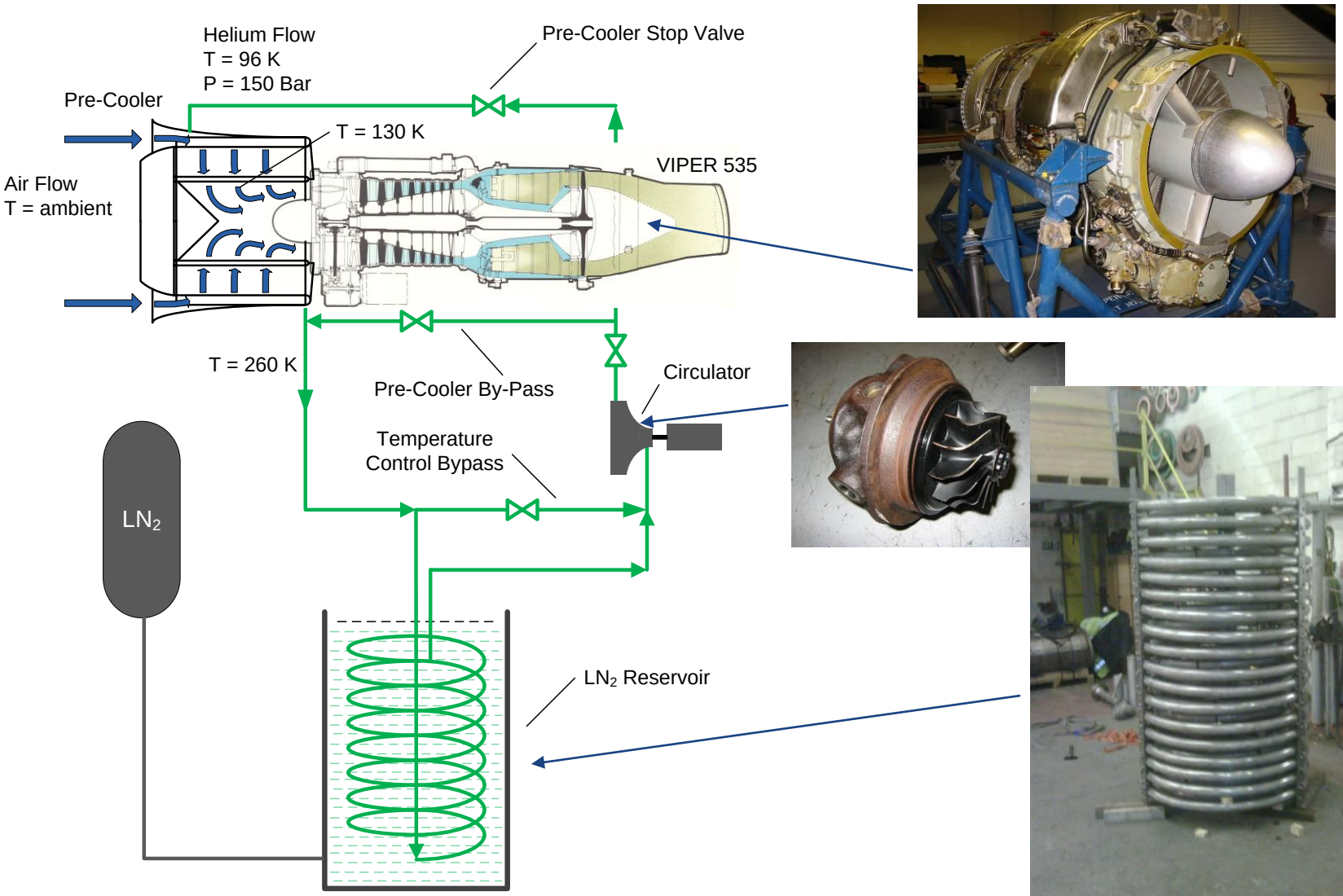
Precooler Modules

Pre-Cooler Testing at Reaction Engines B9

REACTION ENGINES



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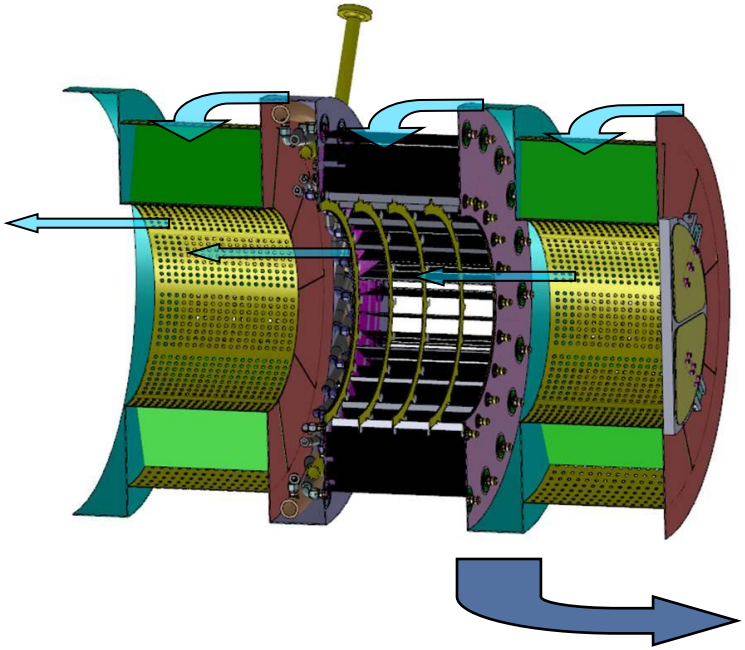
Pre-Cooler Testing



- The Pre-Cooler will be tested at REL's B9 test site using a VIPER 522 jet engine.

REL's B9 installation with VIPER and 'dummy' pre-cooler assembly.

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High Pressure Helium Loop at B9

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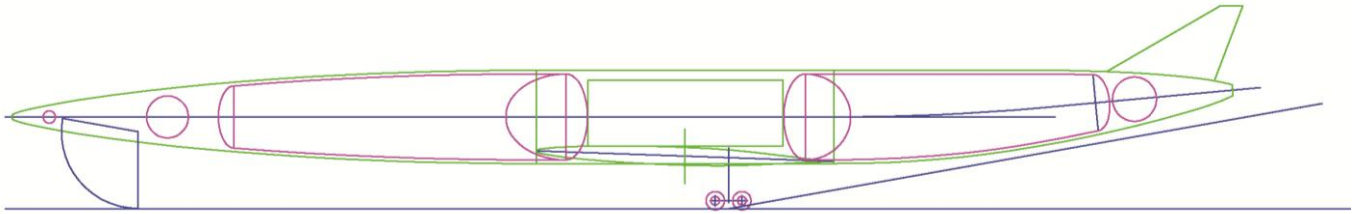
Progress on SKYLON

SKYLON D1

REACTION ENGINES



D1 requirements are now established and validated.

Configuration revision proceeds: a fully trimmed solution has been found, but it will require further study before it can be finalised.

External contributions to D1 design (expand available skill base):

- Aerodyanmic modelling
- Structure loads analysis
- Payload interface
- Avionics and electrical power

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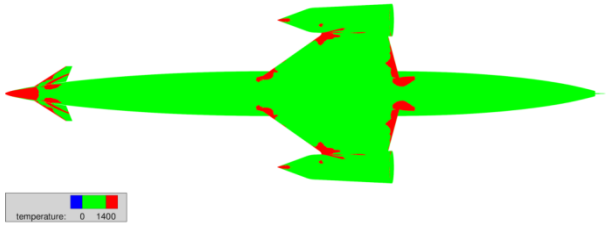
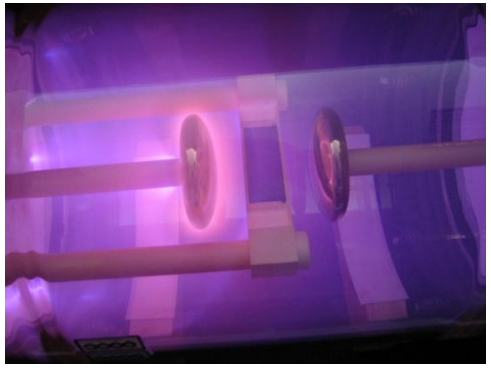
SKYLON D1
Airframe Support Studies

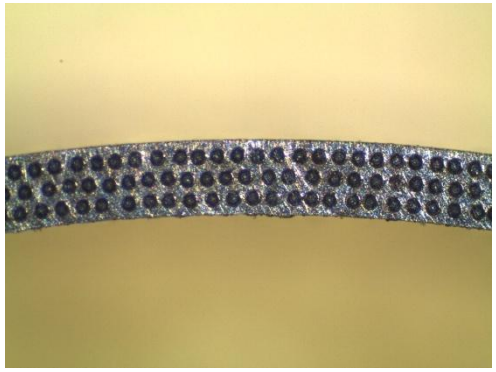
Re-entry Modelling
with DLR Braunschweig using TAU CFD code



Aeroshell Material
with Lateral Logic and Pyromeral



Titanium Matrix Composite Struts
with TISICS Ltd (TSB supported Research)



The Phase 3 Objectives

(30 month Programme)

- Raise engine technology to TRL 6 through ground testing.
- Complete the design of the SABRE4 to manufacturing drawings.
- Ensure that the vehicle requirements and SABRE4 engine design are compatible.
- Flight test the nacelle design (desirable).

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Nacelle Flight Test Vehicle

Length ≈ 9m

Span ≈ 3.5m

Mass ≈ 1000kg

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Phase 3 Programme

Phase 3 Cost Estimate

- Total Engine Programme (with NTV) £220m

Which is comprised by:-

• Airframe requirement studies	£6
• Preparation for Phase 4	£30m
• Engine technology demonstration	£30m
• SABRE4 design	£134m
• NTV	£20m

The engine is the long lead item but the vehicle system design must begin soon in order to meet entry to service in 2021-2022

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SKYLON Review

UK Space Agency independent review

ESA providing technical support

Almost 100 invitees attended two day workshop (Sept 2010)

Part of wider review including on site audit by ESA

REVIEW CONCLUSIONS

'no impediments or critical items have been identified for either the SKYLON vehicle or the SABRE engine that are a block to further developments'.