The implications of UK requirements on the basis of SMR design

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Civil Nuclear
9th June 2016
Our Business

Civil Aerospace
Defence Aerospace
Power Systems
Marine
Nuclear

<table>
<thead>
<tr>
<th>order book</th>
<th>underlying revenue</th>
<th>underlying profit</th>
<th>employees</th>
<th>countries where present</th>
</tr>
</thead>
<tbody>
<tr>
<td>£76.4bn</td>
<td>£13.4bn</td>
<td>£1.4bn</td>
<td>50,500</td>
<td>46</td>
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</tbody>
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Rolls-Royce
Rolls-Royce nuclear power plant

- Power density circa 1000 x Civil Nuclear plant
- Enough fuel for 25 years
- Noise transmitted the same as a car at idle
- Warship power plant not a mini civil nuclear generation plant
Next generation nuclear propulsion plant: PWR3

• New reactor core
• No full nuclear prototype
• New materials and manufacture techniques
• Circa £800M customer investment to date, >600 engineers
Maritime Underwater Future Capability

Propulsion plant vision

Further evolution with up to 20% more power in smaller hull, with lower engineering and unit cost

- Even greater power density
- Advanced manufacturing - 2 year make time
- Advanced modelling “design & develop in the computer”
Reduce capital:
Commoditised; Standardised; Factory built; transportable

Manage Investment: reduce overnight financing; maximise return on investment

Reduce O&M: minimise maintenance / outages, standardised parts, ease of assembly / reassembly minimise Manning.

Reduce Fuel cost: Maximise fuel life, minimise refuel time, simplify fuel / waste handling, use existing infrastructure and capability, efficient

Maximise power: max power density, max output, maximise power generating life

Maximise power/ reliability: high reliability, enable rapid maintenance / refuel.

CoE (£/MWhr) = \frac{(\text{capital} + \text{total O&M} + \text{fuel costs})}{\text{Power Generating potential} \times \text{Capacity factor}}

Compatibility with Support Infrastructure and Sites

Public Perception

Utility Familiarisation / Selection of Technology: confidence in investment

Global Market

Delivery Partnership Potential

Regulatory / Safety: licensable in short time scales; maximise proven technology

Proliferation Resistant: low enrichment levels, secure

Market Opportunity Timing: In construction in leading 2/3 SMR technologies

Strict Design / Manufacture Code Compliance:
New technologies require a launch customer commitment to de-risk the development programme

• An engine development programme takes many years and a large investment

• Long payback periods driven by volume of sales and through life support

• A launch customer is critical to underpin the large investment in engine development

• New technologies present a risk (development programme, regulatory, customer). They must be proven before being introduced into the market.
The dynamics of an SMR investment model are similar to those of a large civil aero engine

Rolls-Royce Trent XWB engine

- Very large R&D programme (IP generative) with long development timeframes to first commercial flight
- Onerous testing programme to meet regulatory requirements
- Full modular construction to reduce Original Equipment cost
- Long term, service based customer relationships
- Long term and global market with many customers providing volume
Design for ease of Licensing

- Most countries have their own aviation authority
- Certificate of airworthiness must be obtained
- Tests include:
  - Flight tests
  - Cold weather
  - Hot & High
  - Water ingest
  - Bird strike
  - Blade off
Design to reduce Manufacturing and Assembly cost

- Factory design to minimise overall capital, optimise factory flow and delivery certainty.
- Modularity is about optimising factory flow, assembly time, and transportation costs.
- Modern manufacturing methods, tools & processes must be developed and introduced in a controlled manner.
- The market must be capable of creating economies of volume to drive manufacturing economies.
- Avoid extremely custom, very expensive facilities and technologies that can reverse economies of volume benefit.
Design for operation and maintenance

• Efficiency of operation throughout the flight envelope is key to optimising overall costs

• Design for simplicity and maintenance must be built in at early design stages to reduce product maintenance costs

• Use of predicative performance methodologies such as analytics for intelligent equipment health monitoring systems to reduce unplanned maintenance

• TotalCare™ type services to Customers can change business models
**CoE (£/MWhr)**

\[
\text{CoE (£/MWhr)} = \frac{\text{capital + total O&M + fuel costs}}{\text{Power Generating potential} \times \text{Capacity factor}}
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**Proliferation Resistant**

**Delivery Partnership Potential**
Key Design Principles

1. Deployable on grid by 2028
2. Minimise cost: capital and through life
3. Must be licensable in the UK (primary) and global
4. Minimise need for operator reliability / maximise passivity
5. Incredibility of failure
6. Resilience to external hazards
7. Maximise power density – max power for a given size (commensurate with commoditisation)
8. Modularisation of design – in terms of factory build, transport and assembly at site
9. Maximise assembly and commissioning off site
10. Minimise size of modules to transportable limits (a plank of commoditisation)
11. Standardise components and capability (a plank of commoditisation)
12. Reduce manning in all aspects – build, security and O&M
13. Minimise maintenance and refuel outage time
14. Minimise waste
15. Flexible power generation and applications
16. Integrate with existing UK / Global infrastructure and capability
17. Maximise site application flexibility
18. Utilisation / Capacity Factor >90%
The civil airframe market has seen considerable change over the last 40 years.
Providing markets for both large and small aircraft

...with the highest volume being in the smaller ‘single aisle’ class

Different airlines operate different services:
- Hub vs A-B
- Flight distance demand
- Passenger numbers
- Airport location(s)
- Physical airport size(s)
Some high profile projects have failed to meet market and customer needs…

- Dassault Mercure – 12 units built
  - Flying range of aircraft insufficient to meet **customer requirements**

- Tupolev TU-144 – 16 units built
  - Pushing the edge of **technology**, the aircraft was blighted by accidents leading to withdrawal from service

- Concorde – 20 units built
  - Sales suffered from **regulatory restrictions** imposed and **poor operational economics**
Are there parallels between the SMR market and the civil airframe market of 40 years ago?

Sample of current SMR vendors

**Russia**
- OKBM Afrikantov
- KLT 40S
- ABV-6M
- RITM-200
- VBER-300
- AKME - SVBR-100
- Gidropress - VVER-300
- RDPE
- VK-300
- Unitherm
- BREST-OD-300
- NIKIET - Shelf

**Korea**
- KEPCO – SMART
- KAERI - SMART

**Japan**
- MHI – IMR
- Toshiba – 4S

**Indian Federation**
- OKBM Afrikantov
- KLT 40S
- ABV-6M
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**India**
- NPCIL – PHWR 220
- BARC - AHWR300-LEU
- IGCAR – PFBR-500

**France**
- Flexblue
- Areva - Antares
- Gidropress - VVER-300
- RDPE
- VK-300
- Unitherm
- BREST-OD-300
- NIKIET - Shelf

**Brazil**
- FURGS (Federal Univeristy of RioGrande) - FBNR

**US**
- B&W - mPower
- NuScale
- Westinghouse – SMR
- Holtec – SMR 160
- General Atomics - GT-MHR
- GE / Hitachi - PRISM
- Gen V Energy - Hyperion

**Argentina**
- CNEA - CAREM

**China**
- CNNC
- CNP600
- ACP100 & ACP100+
- Tsinghua university - HTR-10
- CNEIC - CEFR

**UK**
- U-battery

**UK**
- Flexblue
- Areva - Antares

**France**
- Gidropress - VVER-300
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Food for thought…

Vendors want to produce a design that customers will buy

The UK needs to express clearly what it wants or decision making will be difficult
Trusted to deliver excellence