# CSIRO SpaceFSP Webinar

## Space Battery Design: It's not just a battery

*Dr. Glen M. Brown, Boeing Commercial Airplanes*

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## Response to Questions

During the Webinar, we were asked plenty of questions, but time didn't allow us to answer them all. Here you find the questions and the brief response from the presenter and moderator. If you would like further information beyond the responses provided here, please contact Dr. Adam Best. We also thank all those people who thanked the speaker for the excellent talk – we appreciate it!

Please note, the questions may have been edited for clarity.

| Question # | Question | Response |
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| 1 | Fascinating stuff, presumably there are also efficiencies and optimisations of the power users that drain the battery, in terms of research and development, what proportion goes to battery design and then to power usage of tools in the payload (eg. low power usage) – Nick | Yes, systems architecture and power budgeting is very important in spacecraft and mission design. For spacecraft applications, the batteries are "only" used during eclipse, and are designed to support the entire spacecraft power needs including the payload. In addition to the payload, other consumers of power include things such as on-board heaters and some back-up systems, which need to be considered as part of the overall power budget. |
| 2 | I remember lithium batteries being rather flammable, and taking them on a plane, there are restrictions, aren't they still flammable and how are space batteries different to commercial batteries in relation to this? -Nick | Thanks for the question, Nick. Glen answered your question in the presentation |

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| 3 | What is Moore's law for space batteries? – David C | For space batteries, it is very slow, since one of the critical aspects of space mission design is mission performance and reliability, which relies upon a very stable, predictable, cell / battery design and performance. While battery tech itself is evolving rapidly, batteries specifically tailored for space evolve very slowly due to lead times required for qualification and to maintain performance, predictability and reliability. |
| 4 | Glen, thank you for your presentation. I wonder if you could make some comments on LEO and typical work vs performance temperature ranges you have been facing with. Also do you have independent batteries for different systems (e.g., payload vs thermal). Thanks (from Griffith University, we miss you here) – Paolo d S | Thanks for the question, Paolo. Glen answered your question in the presentation |
| 5 | How much can suppliers mislead on battery performance and are there any suppliers which can be “trusted”? – David C | Thanks for the question, David. Glen answered your question in the presentation |
| 6 | In terms of optimization for weight and insulation, have batteries been designed to be incorporated into a satellites body (shell or frame) or other components (solar arrays)? Or does changing the geometry affect the battery performance too much? – Tim H | Yes, the design of batteries is optimized for weight and volume and may be designed to be incorporated into or onto spacecraft structure, depending upon overall spacecraft design. And the battery design needs to be such that the performance of the battery is optimized to meet mission / customer requirements. |
| 7 | What will stop the electricity from escaping into space? [Harry, 9 years] – Jenni W | Thanks for the question, Harry! Glen answered your question in the presentation |
| 8 | What lessons can we learn from the Boeing 787 lithium battery experience - Anonymous | Many valuable lessons were learned from that experience which have been well-documented and available in the public domain. |

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| 9 | Hi. Silly question. Will you send the link to the recording to our emails? Thank you. – Luke C | Yep, the link is on the first page |
| 10 | Could Graphene material potentially be used as a protective surface for cells? – Robert B | Potentially, but currently many low-cost options or options that are relatively easily applied are used, mainly due to cost and processing time. |
| 11 | How can COTS [ed: Commercial Off The Shelf] batteries be adapted for space and where can such information be accessed? More generally, how much is space battery design knowledge in the public domain and how much is ""trade-secrets""? – David C | There is a considerable amount of information in the public domain. I would refer you to material published by NASA. Enersys (formerly ABSL) have flown many COTS based solutions in space. And in recent years (the past decade) the use of COTS cells for space missions is increasing. Having said that, it is important that any COTS cell being considered for space mission be fully tested and evaluated (electrically, mechanically, thermally) to ensure it is capable of meeting the requirements of the space mission with the required margin. Much information is company proprietary, but there is considerable public information available. |
| 12 | Many thanks for this informative presentation. You covered Li-ion batteries extensively but are other battery types still used? $NiH_2$ for example? Ned E-D | Yes, mainly focussed on Li ion. $NiH_2$ batteries are still flying on various space missions, but to my knowledge they are no longer being produced. With the progression of Li ion technology (and much more favourable energy density), along with obsolescence issues being experienced with some base materials that were used in $NiH_2$ cell electrode production, the industry transitioned from $NiH_2$ to Li ion over the past decade. |
| 13 | What considerations should be given to the design of medium/high voltage batteries for operating in the critical low pressure region of earth atmosphere or other planets? – Tanan H | Space battery design should adopt sound insulation and protection of all aspects of the electrical circuitry, ensuring no exposed metal, (insulation, conformal coating, kapton tape layers |

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| | | etc). Consideration should be given to harness routing, and dynamic clearances to ensure no compromising of aspects of the design due to vibration. |
| 14 | Is future on-orbit servicing of batteries a possibility? David C | Interesting question……on orbit servicing of spacecraft have been considered in terms of adding propellant fuel, but I am not aware of on orbit servicing of batteries. Ultimately batteries age as a function of cycling and usage……and so they would need to be replaced versus serviced. As an example, older $NIH_2$ batteries on the ISS were recently replaced with Li ion batteries. |
| 15 | How involved do you tend to get with the fundamental cell design? – David Co | We, at Boeing, typically do not get involved in cell design. Our approach is to work closely with, but to rely upon expertise of cell suppliers. |
| 16 | Are there power to weight values for different types of batteries? – Anita H-B | Yes indeed! This is often influenced by the mission and spacecraft requirements. Ultimately we need to optimize weight and volume, but the structural, dynamic (shock and vibration) and thermal requirements may influence the structural aspects of the battery design, which in turn will ultimately impact the energy density of the battery. |
| 17 | Touching on temperature considerations of the battery - How might you consider the temperatures of space/the sun in battery design and engineering? – Anonymous | The thermal design and control of the battery is extremely important. Cell (and battery) performance and cycle life is affected by temperature and so the battery must be designed to provide an optimal thermal environment to optimize the battery performance over its life. Radiators are sized to maintain appropriate thermal management of the battery to dissipate heat away from the battery to ensure it |

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| | | does not get too hot. And similarly heaters are used to ensure the temperature is maintained to ensure the battery does not get too cold. Establishment of temp set points and balance between heater sizing and control and radiator design is very important. Ageing of cells, resulting in impedance increase also leads to thermal dissipation during cycling, and radiators also age with time, so radiator degradation (and efficiency) also needs to be considered. |
| 18 | Do space radiation effects in higher orbits tend to affect the battery systems more or less than other payload systems? David Co | Good question. I don't know that radiation effects necessarily effect the battery more than payload systems per se. It is important that rad-hardened components be selected depending upon the specific orbit, mission life and requirements. For the battery, similarly, it is important to consider radiation effects on cell performance degradation (and affects on cell chemistry and materials degradation). Depending on the mounting location of the battery on / in the spacecraft this effect can vary, depending upon the degree of shielding of the battery. |
| 19 | Are you considering hydrogen batteries for the future or are the Li-Ion batteries still the way to go for the foreseeable future? - Claudia | Li ion batteries have essentially superseded the use of $NiH_2$ batteries for space, which are now obsolete. Li ion batteries will be used for the foreseeable future. |
| 20 | Do you see benefits of using larger format battery in space applications? and perhaps comments on its design challenges too? – Handa Xi | There are a variety of different cell formats used in space today, including small, medium and very large format cells. So, almost any format can be used. Ultimately choice of cell becomes a design trade to optimize the battery design in terms of power, weight, volume to meet the spacecraft design and mission requirements. For |

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| | | some spacecraft designs, larger formats will provide an optimal design approach, while smaller formats might be best suited for other spacecraft designs, depending upon the spacecraft layout / design. |
| 21 | Is there a role for EDLCs (supercapacitors) in LEO and GEO programs? – Anthony K | Potentially, but there are not too many spacecraft applications requiring high pulse power. There may be some potential military needs that could potentially use something like this. |
| 22 | What role is Australia's emerging battery materials mining and processing sector likely to play in the area of space batteries - particularly given NASA ramping up its space/moon exploration programs? – Simon W | Thanks for the question, Simon. Australia's battery minerals sector is one of the world's largest, but we lack the processing facilities to be able to prepare materials that go into both COTS and space batteries at this time. However, through a number of initiatives, CSIRO and the Australian Space Agency are involved in programs with NASA for battery development amongst other things – Adam. |
| 23 | Will this video be available off-line for those of us who would like to review the presentation or may have missed the starting? | Yes. |
| 24 | Isn't it only a matter of time before Li Ion cells are super ceded? – Robert B | Yes, in due course I would expect next Gen Li ion, or "beyond LI ion" technologies to eventually be used, as the technology evolves. |
| 25 | There is a need for recurring use of batteries in your satellites. How do you ensure that you maintain the heritage cell designs and chemistry with the commercial cells? Ratnakumar B | Glen answered this question in the presentation |
| 26 | Are there any new technologies that NASA is currently working on other than lithium? For example solid State batteries - Mahdi | Yes, various Li -ion based chemistries (for a variety of temp environments and cycle regimes) are being explored as well as solid state chemistries. LiS chemistries are being evaluated, as well |

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| | | as high temp and low temp operating batteries. |
| 27 | How reliable/difficult is the cell performance or life-time prediction for many 1000 cycles, in particular if cells show a sudden capacity drop? – Thomas R | Life testing of cells and batteries in advance of the mission is very important to ensure that stable, reliable life performance models are developed. These models are then used to validate battery design and spacecraft mission requirements, and to monitor on orbit performance. Battery design also needs to consider failure / fault conditions such as for a failed cell case. Depending upon the criticality of the mission, customer and mission requirements and battery design, some batteries are equipped with cell bypass capability in order to by-pass a cell that has failed / failing. Batteries also ought to be designed with some degree of redundancy to mitigate a failed cell. This is challenging, depending upon the battery and spacecraft power architecture. |
| 28 | Could you please comment on how context affects research? Have you seen approaches differ between Australia, Japan and the USA for example? - Anonymous | I am assuming the question relates to battery research. There is excellent capability in each of the countries listed. Ultimately “critical mass” and availability of corporate or government based funding is a key discriminator. And then, research is often influenced by the potential markets being targeted. There are cultural and corporate cultural approaches that do vary from country to country, and depending upon the heritage of a given country or entity in the field of battery research, risk averseness, or innovativeness that is generally adopted also varies. |
| 29 | Is it requirement to have each cell monitored by the BMS? – Stefan B | There is not a requirement per se, and this will vary depending upon the |

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| | | battery architecture and types / formats / and quantities of cells in a given battery. |
| 30 | Thanks awesome talk and discussion – Nick | Thank you Nick! |
| 31 | Great presentation - thank you! apologies if you have said earlier, will we get a copy – Luke C | See on the first page. |
| 32 | My preferred question is on Moore's law for batteries. I.E how much will they improve | Very low / slow for space batteries. And in Li ion technology generally, cell capability is currently advancing at a rate of a few (~5%) per year. There is a lot of active research aimed at achieving step function advancements in capability, by going from Li ion to Li metal based systems etc. |
| 33 | How can we get alerted about future webinars like this? | Yes, you'll be able to find more presentations like this on https://research.csiro.au |