



Space Power System Transformation: LEO Fleets and Lunar Expeditions (2022 SPW - PMAD WORKSHOP)

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Power System Challenges - Building for the Future

- Historically, most S/C Power Systems have been fully A/B Redundant, and hand-crafted in small batches
 - *Full Redundancy has allowed Mission continuation in spite of failures*
 - *Class “S” Parts are heavily screened and tested in multiple Environments*
 - *Full “Pyramid” testing at the board, box, pallet, and System level weeds out design & workmanship escapes*
 - *Once on Station, these Heritage designs typically last 2-3x specified Mission life*
- Falling Launch costs and increased access to Space have now led to many new entrants
 - *Proliferated LEO is now driving to fleet reliability; individual S/C primacy can be reduced*
 - *Use of COTs parts allows more capability in smaller packages at lower prices*
- PLEO needs are for much higher volume, lower individual cost, mass production, and reduced touch labor
 - *Point-design for highest efficiency and full redundancy has been traded by the community*
- Upcoming Lunar missions have high transit costs, low vehicle counts and long replacement timelines
 - *Reliability / fault-tolerance are again very important here, but with COTs parts and at much reduced size & weight*
 - *Fail-Soft with m-for-n channelization preserve Mission with part failures, but reliability calcs must take this into account*
 - *Designs with many single string functions will find it difficult to compete with more robust systems*

Power Systems are using COTs parts, but two trends are emerging: mass-produced PLEO and Lunar expeditions



Proliferated (P)LEO constellation Power System Keys

- Low-Cost COTs piece-parts have proven themselves to be OK in Space
 - *Automotive-Grade COTs parts are widely available (over 20,000 FETs on Digi-key, vs 250 Rad-Hard parts at IRF)*
 - *Cost of COTs parts is 100x lower than Class S*
 - *Parts are widely available & in stock at multiple Vendors*
 - *High production runs of >10,000 parts mean pass-fail goal-posts are narrow and demonstrated failure rates low*
- Full SMT designs on rigid-flex PWBs are possible
 - *Full SMT requires no touch labor for assembly or test*
 - *Automated manufacturing means no more mis-placed or incorrect parts on a board*
 - *Rigid-Flex PWBs & mezzanine connectors can eliminate all wires (touch labor, routing errors, pinching) inside a box*
- Generous parts deratings increase reliability
 - *Part temperatures & stress levels are lower; this translates directly into longer life*
 - *Large deratings equate to simpler stress analysis and low probability of overstress escapes*
 - *Multiple, parallel power circuits allow for lower stress on a good day, and full operation even if one string fails.*
 - *NFETs with 3x or 4x Voltage deratings do not fail in SEE environments; PFETs do not have SEGR concerns*

COTs parts, SMT-technologies, and robust design margins all increase Reliability