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Radiation and Power Predictions for Electric Orbit Raising, a Case Study

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MAXAR Radiation and Power Predictions for Electric Orbit Rising (EOR), a Case Study

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MAXAR

SCITech, 1/6/20 – 1/10/20

Orlando, Florida

Electric Orbit Raising to GEO

- Commuting to GEO by EOR is like biking to work
  - Driving is fast and easy, but you need gas (or a very large battery)
  - Biking is more efficient, but requires more planning
    - Need to map out a safe route
    - Need proper safety equipment
    - Need to plan for weather
  - Similar planning and preparation is needed for EOR

Benefits of Electric Orbit Raising

- Less propellant mass required
- More mass available for payload
- More launch options

- But…
  - It takes longer (many months)
  - Greater radiation exposure
  - Needs more solar array power

- Hence, more planning is needed
  - CONOPS require daily power predicts during EOR
  - The belts are constantly changing
  - Solar events can happen
  - Initial drop off matters

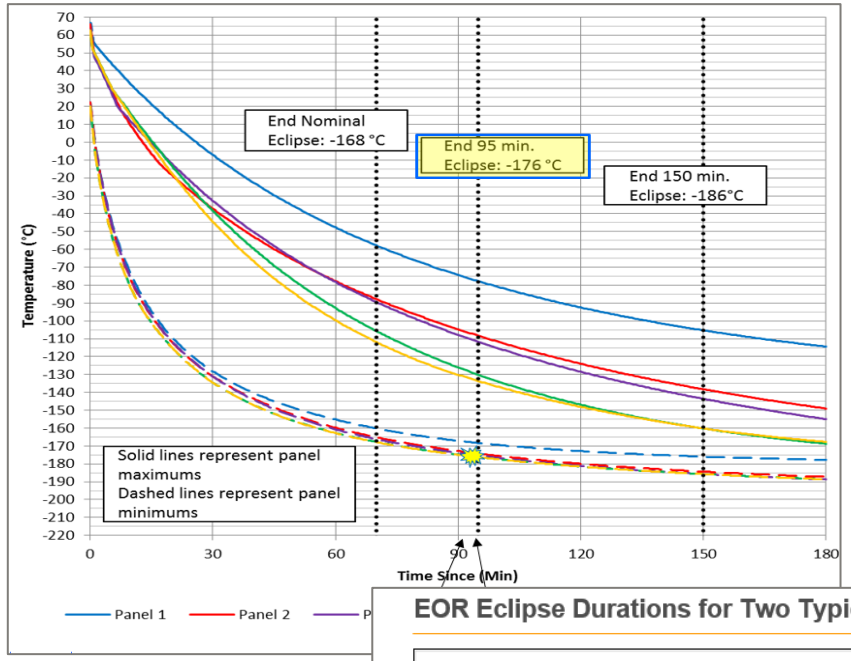
Credit: SpaceX
Falcon 9 launches Telstar 19 Vantage

Maxar EOR Experience

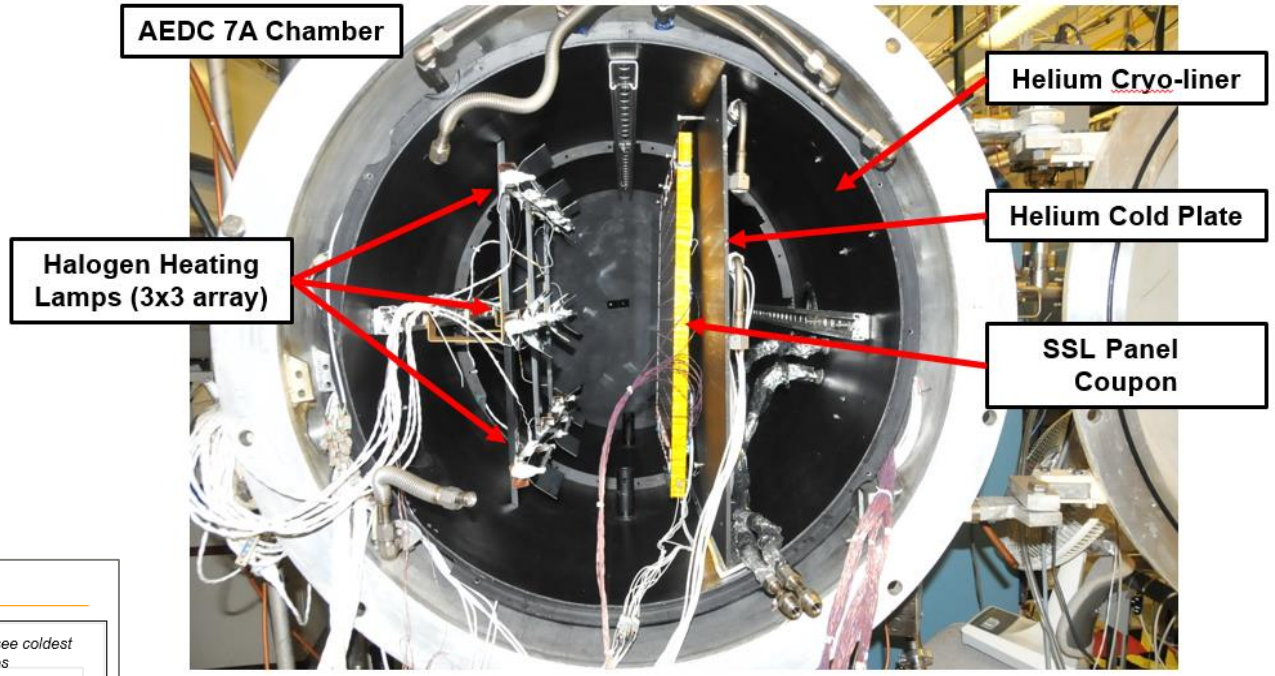
- Electric Orbit Raising has been performed for a small number of Maxar GEO spacecraft
  - This presentation considers Maxar's first EOR and the resulting lessons learned

- Preparation for EOR
  - System Engineering looked at 60+ launch vehicle and EOR scenarios in order to bound thermal environment for the product line
    - Eclipse times can exceed those of GEO, resulting in colder temperatures
  - Solar Array Engineering conducted supplemental coupon Thermal Vacuum Testing to delta-qualify both our heritage Rigid Panel and new ROSA wings to lower temperatures
  - Power predictions generated by Space Environments and Solar Array Engineering for end of EOR
    - Ae8, Ap8 models used to predict radiation
      - Electron and Proton fluence
    - Use of heritage GEO power analysis model

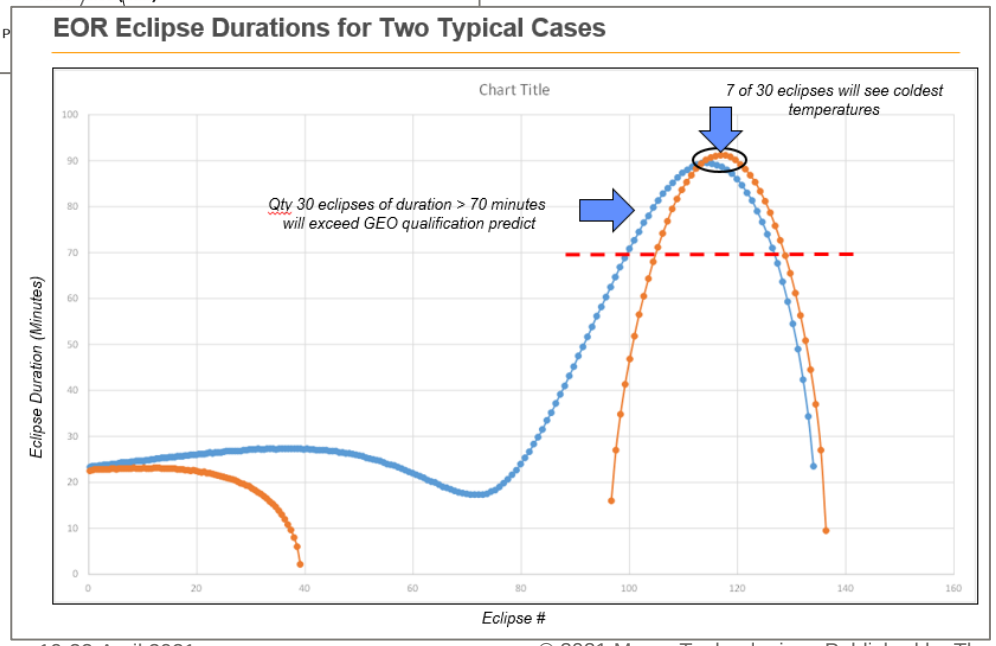
Thermal Predicts for a 5-panel Rigid wing at 43,437 km



- EOR Eclipse time for this mission was 95 mins
- Nominal min temperature of -176 °C



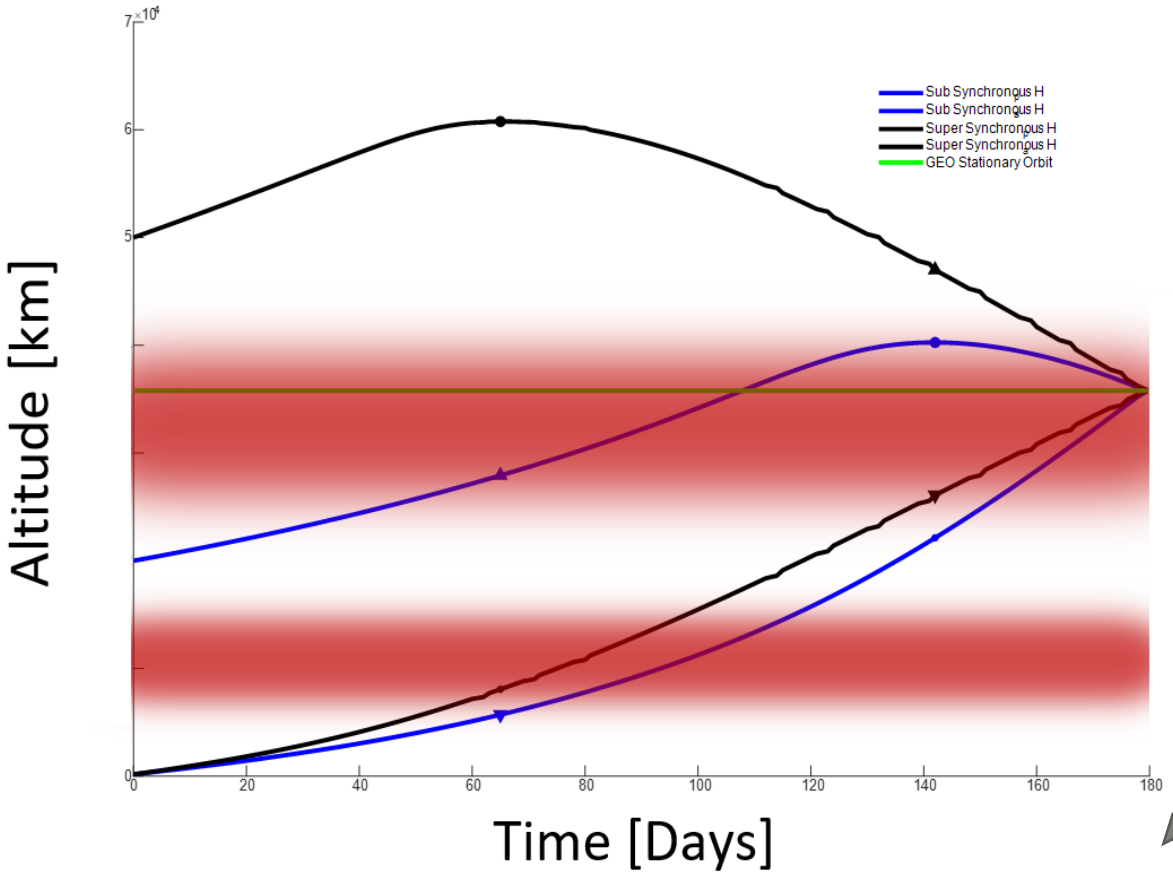
- ~140 eclipses during EOR for this mission
- Of those, 30 exceeded GEO temps



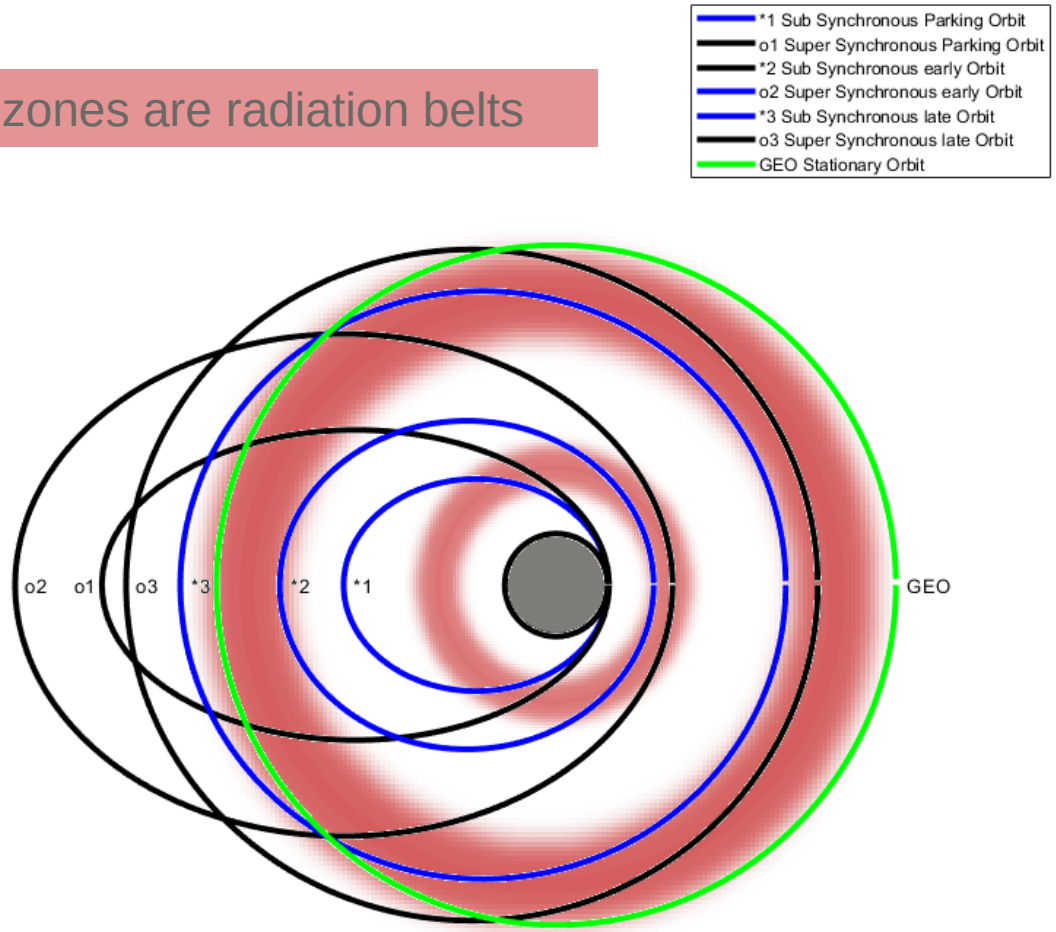
- MELCO and NEC rigid substrate panels tested down to -190 °C for 30 cycles (mission-specific)
- ROSA coupons cycled down to -230 °C for 30 cycles
  - Additional cycles planned on ROSA coupons to envelope product line

EOR Orbit and Radiation Exposure May Vary

- Longer duration does not always mean “worse” – not a direct correlation
- Initial drop-off point is more important



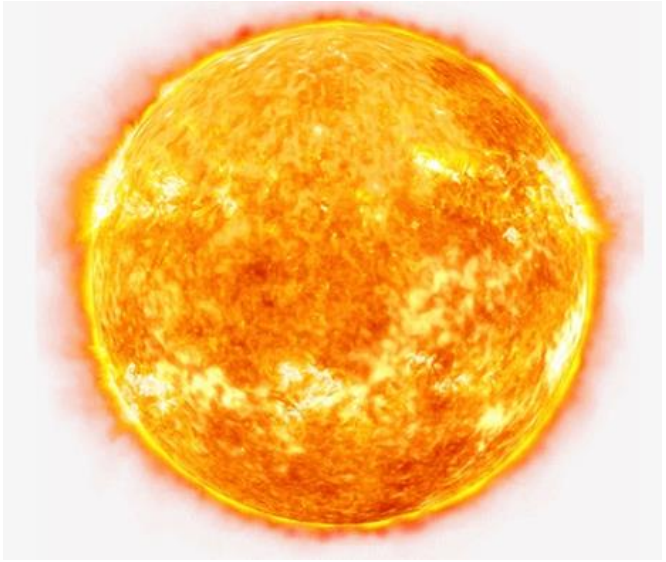
Red zones are radiation belts



Blue line and Black line EORs have same duration, but Blue sees more radiation

Electron and Proton Environment and Predictions

- Ae8 and Ap8 legacy models
  - Ae8 maximum mean
  - Ap8 minimum mean
  - Known limitations
    - Uncertainty in radiation belts
    - Solar events not captured
- IRENE successor model
  - 75th, 90th, and 95th percentile
  - Known limitations
    - Model error ~3x in radiation belts
    - Belt dynamics not captured
    - Solar events not captured
- During a typical EOR
  - Increased proton flux in lower belt, compared with GEO
  - Increased electrons in upper belt, compared with GEO
- This mission EOR
  - No significant activity in the magnetosphere



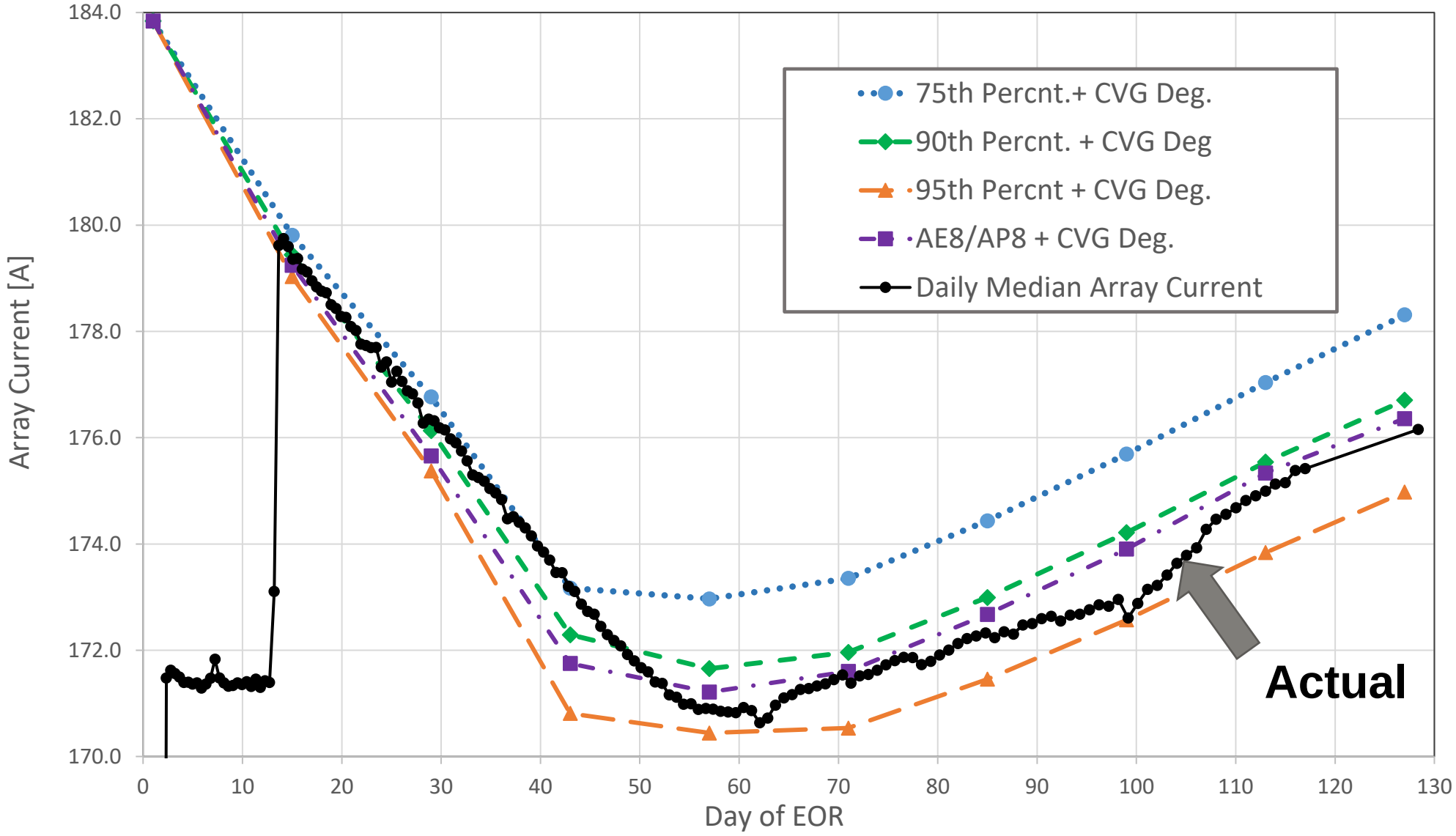
Initial Solar Array Power Predicts and EOR Lessons Learned

- Heritage GEO power prediction tool used for analysis
  - Coverglass darkening due to Protons not seen for many missions
    - Due to relatively quick GEO Transfer Orbits (~2 weeks)
  - Known to be a factor in LEO, based on work done with NREL*
  - Ran Ae8 and Ap8 for the initial planned EOR

- During this EOR, actuals began to depart from extrapolated expectation
  - A tiger team was convened to investigate and review models
  - Updated factor for Low Energy Proton (LEP) coverglass darkening to 2.55%*
  - Updated Ae8 and Ap8 models for as-flown EOR
  - Ran IRENE for 75%, 90% and 95% confidence intervals

*"Low-Thrust Geostationary Transfer Orbit (LT2GEO) Radiation Environment and Associated Solar Array Degradation Modeling and Ground Testing", Scott R. Messenger, Frankie Wong, Bao Hoang, Cordy D. Cress, Robert J. Walters, Craig A. Kluever, and Glenn Jones. *IEEE Transactions on Nuclear Science, Vol. 61, No. 6, December 2014.*

Program Actual Solar Array Current vs. Prediction (During EOR)



Maxar Standard Practice Moving Forward

- Include coverglass darkening factor for Low Energy Protons during EOR

- Start with either
  - 90th percentile IRENE model
  - Heritage Ae8 / Ap8 with 20% margin

- Run power predict for exact orbital position for every 1-2 days during EOR
  - More work than just a point predict at EOL like heritage
  - Need precise positional data from Orbits group, for each day, during entire EOR
  - Need to “turn the crank” on radiation model for scores of cases (an overnight task, 20-30 hrs of run time)
  - Run solar array power tool for specific radiation at each point

- Need to understand where the “knee” happens in the power curve

Conclusions

- Solar arrays can get really cold during EOR
  - May need a delta qualification in a He-equipped chamber

- EOR radiation can be significant
  - Account for Proton degradation of coverglass (2-3%) – see cited paper
    - Maxar is conducting supplemental testing to better characterize this factor
  - EOL power can be ~5% lower as a result of EOR (varies by program)
  - Depending on solar cell type, more losses can be seen in voltage
    - Don’t skimp on string voltage in your design (when in doubt, add cells in series)

- Other, future EORs may be different and Maxar continues to incorporate lessons learned as we experience more EORs

Note that EOR power needs can end up driving solar array sizing

Thanks to the Maxar Space Environments Group

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