APOLLO VS FNPEG ENTRY TERMINAL POINT GUIDANCE COMPARISONS FOR A MARS EDL MISSION

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ABSTRACT

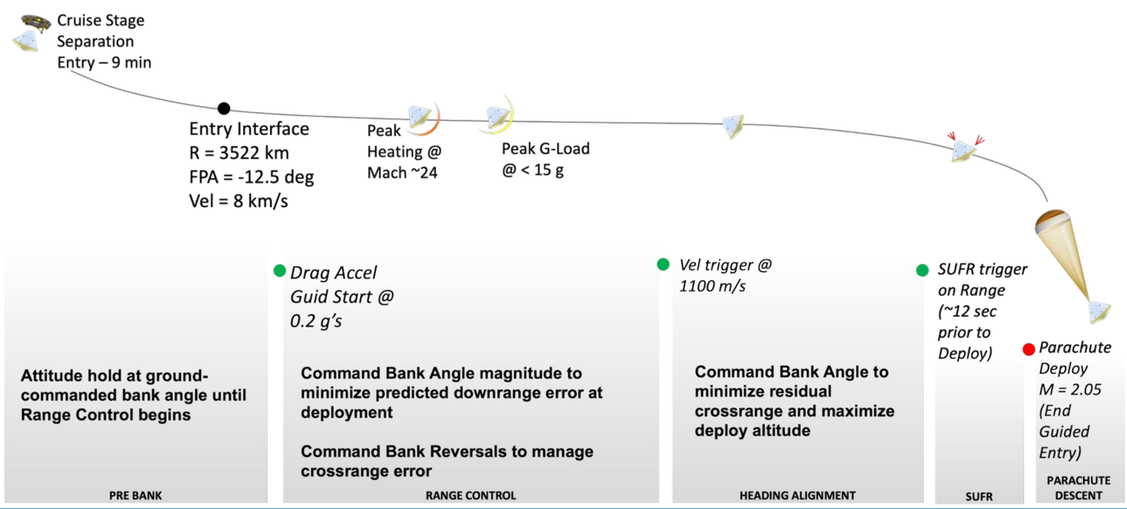
The Apollo Entry Terminal Point Guidance algorithm has flown onboard Mars lander missions but requires significant parameter tuning. For future human to Mars missions, an operationally simpler yet robust guidance is desired, motivating evaluation of the Fully Numeric Predictor Corrector Entry Guidance (FNPEG) algorithm. For a representative Mars low L/D entry, descent and landing mission, Apollo and FNPEG were compared within an established 6 degree-of-freedom simulation. FNPEG improved terminal point precision, reducing downrange ellipse spread by about half, but also decreased terminal altitude by ~2 km, raising parachute deployment load concerns. A mid-point bank energy term may further refine FNPEG and recover altitude performance, similar to Apollo's bi-level reference trajectory approach.

MARS ENTRY GUIDANCE: DESIGN CONSIDERATIONS

- TRAJECTORY CHARACTERISICS
- NAVIGATION (STATE ESTIMATION)
- VEHICLE DESIGN (AERODYNAMICS)
- ATMOSPHERE (SEASONALITY, LANDING SITE)

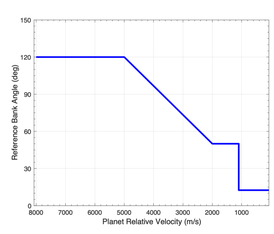
Mission Parameter	Value
Entry Velocity	8 km/s
Entry FPA	-12.5 deg
Peak g-load	< 15 Earth g's
Ballistic Coeff	~220 kg/m^2
L/D	0.29
Landing Site	Mid-Northern, ~10 km Deploy Altitude

MARS ENTRY GUIDANCE: PHASES

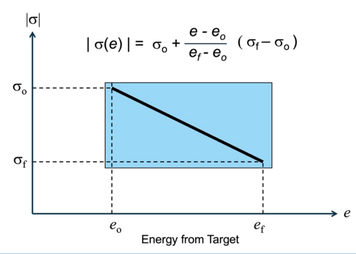


ALGORITHMS

- APOLLO
  - Predictor
  - Stored reference bank profile
  - Uses calculated gains for L/D control



- FNPEG
  - Numerical Predictor-Corrector
  - Closed–loop linear energy vs bank command



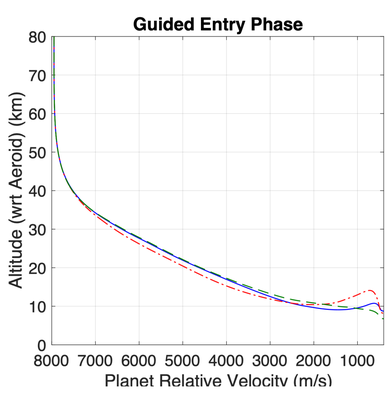
APPROACH

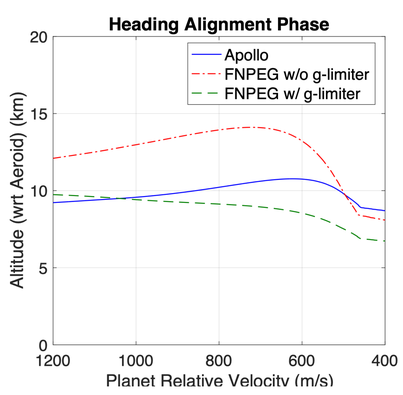
AUGMENT FNPEG TO MATCH APOLLO-LIKE MODELS
- LATERAL DEADBAND SCHEME
- BANK REVERSAL DYNAMICS
- HEADING ALIGNMENT PHASE
- PREDICTOR-CORRECTOR TOLERANCE / BEHAVIORS

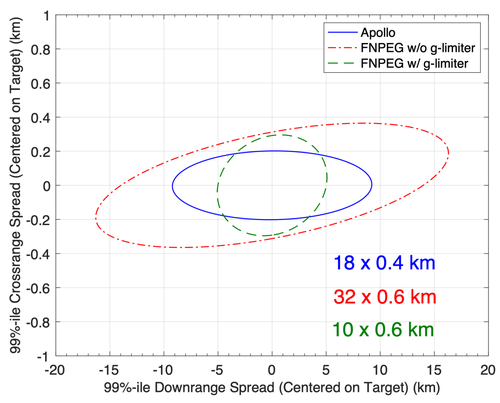
TEST FNPEG UPDATES IN 3-DOF TRAJECTORY SIMULATION

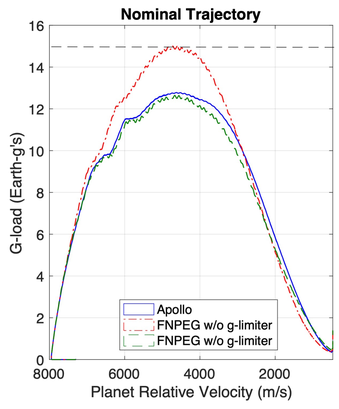
AUGMENT FNPEG AND COMPARE ALGORITHMS IN 6-DOF TRAJECTORY SIMULATION

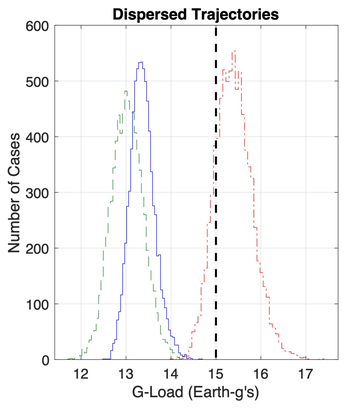
RESULTS











CONCLUSION

FNPEG PERFORMS BETTER THAN APOLLO IN TERMS OF DOWNRANGE PERFORMANCE, HOWEVER AT THE EXPENSE OF ALTITUDE AT THE TERMINAL DEPLOY POINT

FUTURE INTRODUCTION OF A MID-POINT ENERGY-BANK INTO THE FNPEG SCHEME IS PROPOSED, SIMILAR TO THE APOLLO VARIABLE BI-LEVEL REFERENCE PROFILE FOR MARS TRAJECTORIES TO ASCERTAIN IF THIS AIDS IN RECOVERING ALTITUDE PERFORMANCE DUE TO MARS' LOWER DENSITY UPPER ATMOSPHERE AND NEED FOR MORE CONTROL AUTHORITY PRESERVATION LATER IN ENTRY

Acknowledgements & References

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