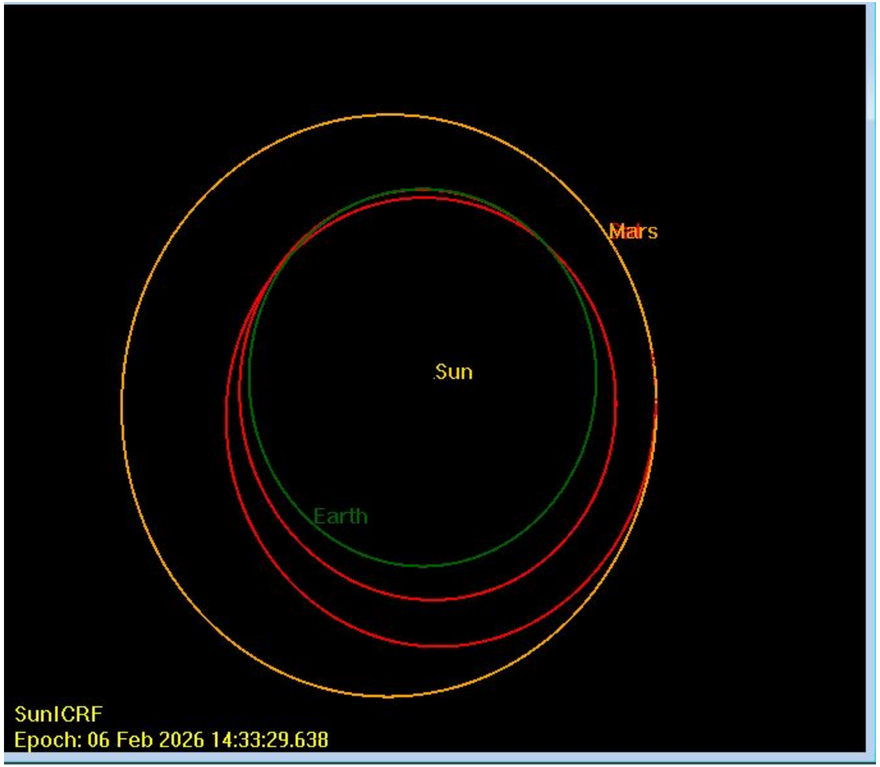
Earth to Mars Problem

- Constant 0.1-newton magnitude
- 3.57e-06 kg/s Mass flow rate
- Fuel Mass 1000 kg
- Fuel Consumption 287.8 kg
- Fixed Started date: July 20, 2023
- End date: February 06, 2026
- Time of Flight: 933 days
- Total number of steps: 200
- Number of Major iterations: 265
  - Total interactions: 7093
- Total run time: 13 hours
- Feasibility: 6.5E-09
- Optimality: 8.0E-07



Earth to Mars Trajectory (Red)

Earth to Mars SNOPT Optimization Setup

- Objective Function: Time of Flight
- Constraints: Spacecraft's relative position and velocity to Mars
- Load initial guess
  - alpha, beta thrust vector angles, and TOF
- Set design variable and function bounds
  - -pi to +pi thrust angle, ½ year to 10 year TOF
  - ObjFun: 0 to 10 years, constraints equal 0
- Run SNOPT optimization
- Calls Objective/Constraint Function
  - Converts design variable into thrust file and updates GMAT propagation time
  - Run GMAT and extract Spacecraft data with API commands
  - Calculated Spacecraft's relative position and velocity to Mars Ephemeris data
    - Compute objective function and constraints

```
Major Minors     Step   nCon Feasible  Optimal  MeritFunction     nS Penalty
  260      1  1.0E+00    267 (3.9E-09) 1.7E-06  1.6042772E+01    274 3.8E+03        c
  261      1  1.0E+00    268 (1.5E-09) 1.5E-06  1.6042771E+01    274 3.8E+03        c
  262      1  1.0E+00    269 (9.4E-10) 1.4E-06  1.6042771E+01    274 3.8E+03        c
  263      1  1.0E+00    270 (2.2E-09) 1.3E-06  1.6042771E+01    274 3.8E+03        c
  264      1  1.0E+00    271 (5.2E-09) 1.1E-06  1.6042771E+01    274 3.8E+03        c
Itn   7093: Elastic weight increased to   2.000E+06
Itn   7093: Elastic weight increased to   2.000E+08
Itn   7093: Elastic weight increased to   2.000E+10
  265      1  1.0E+00    272 (6.5E-09)(8.0E-07) 1.6042770E+01    274 3.8E+03        c

SNOPTA EXIT   0 -- finished successfully
SNOPTA INFO   1 -- optimality conditions satisfied

Problem name
No. of iterations                  7093   Objective             1.6042770094E+01
No. of major iterations             265   Linear    obj. term   0.0000000000E+00
Penalty parameter             3.765E+03   Nonlinear obj. term   1.6042770094E+01
User function calls (total)      122142   Calls with modes 1,2 (known g)     272
Calls for forward differencing   110275   Calls for central differencing   11228
No. of superbasics                  274   No. of basic nonlinears              6
No. of degenerate steps               4   Percentage                        0.06
Max x                         1 1.6E+01   Max pi                       2 5.9E+01
Max Primal infeas             0 0.0E+00   Max Dual infeas             95 4.7E-05
Nonlinear constraint violn      1.0E-07



Solution printed on file   9

Time for MPS input                              0.00 seconds
Time for solving problem                    47294.58 seconds
Time for solution output                        0.00 seconds
Time for constraint functions               47291.89 seconds
Time for objective function                     0.00 seconds
```

SNOPT Output Summary

Future Work

- Search for more optimal solutions
  - Increase Step Size
  - Make start time a design variable
    - Modify start time through API commands
- Have MATLAB-SNOPT-GMAT code working on Linux HPC-cluster to be able to run longer simulations remotely
  - Get a compiled version of GMAT in Linux
- Apply this method to other problems

```
t1=juliandate(2023,07,20,00,00,00);
[Re_i,Ve_i]= planetEphemeris(t1,'Sun','Earth');
load_gmat();
gmat.gmat.LoadScript("C:/GMAT_Repo/EarthToMars_
sat = gmat.gmat.Construct("Spacecraft", "Sat");
sat.SetField("DateFormat", "A1ModJulian")
sat.SetField("Epoch", num2str(t1-2430000.0))
sat.SetField("CoordinateSystem", "SunICRF")
sat.SetField("DisplayStateType", "Cartesian")
sat.SetField('X', Re_i(1));
sat.SetField('Y', Re_i(2));
sat.SetField('Z', Re_i(3));
sat.SetField('VX', Ve_i(1));
sat.SetField('VY', Ve_i(2));
sat.SetField('VZ', Ve_i(3));
```

API Commands to set start time, initial position and velocity of spacecraft in GMAT