ORION EXPLORATION MISSION ENTRY INTERFACE TARGET LINE

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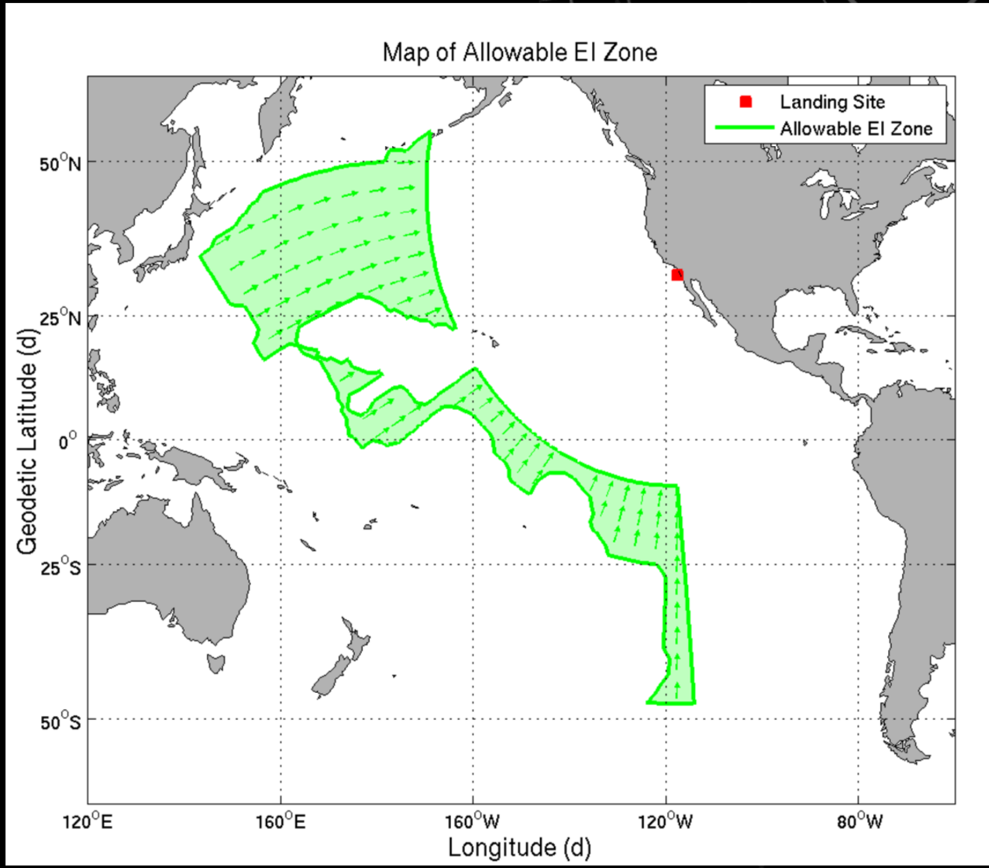
ORION ENTRY CORRIDOR CONSTRAINTS

- Horizontal Constraints
  - Return to San Diego landing zone anytime during the month
  - Preserve weather divert capability to fly up to 1200 nmi short of target
  - Minimum flyable range of 1300 nmi defined by maximum acceleration
  - Dispose of Service Module debris over open ocean
  - Point toward landing site within crossrange capability of vehicle
  - No retrograde entries

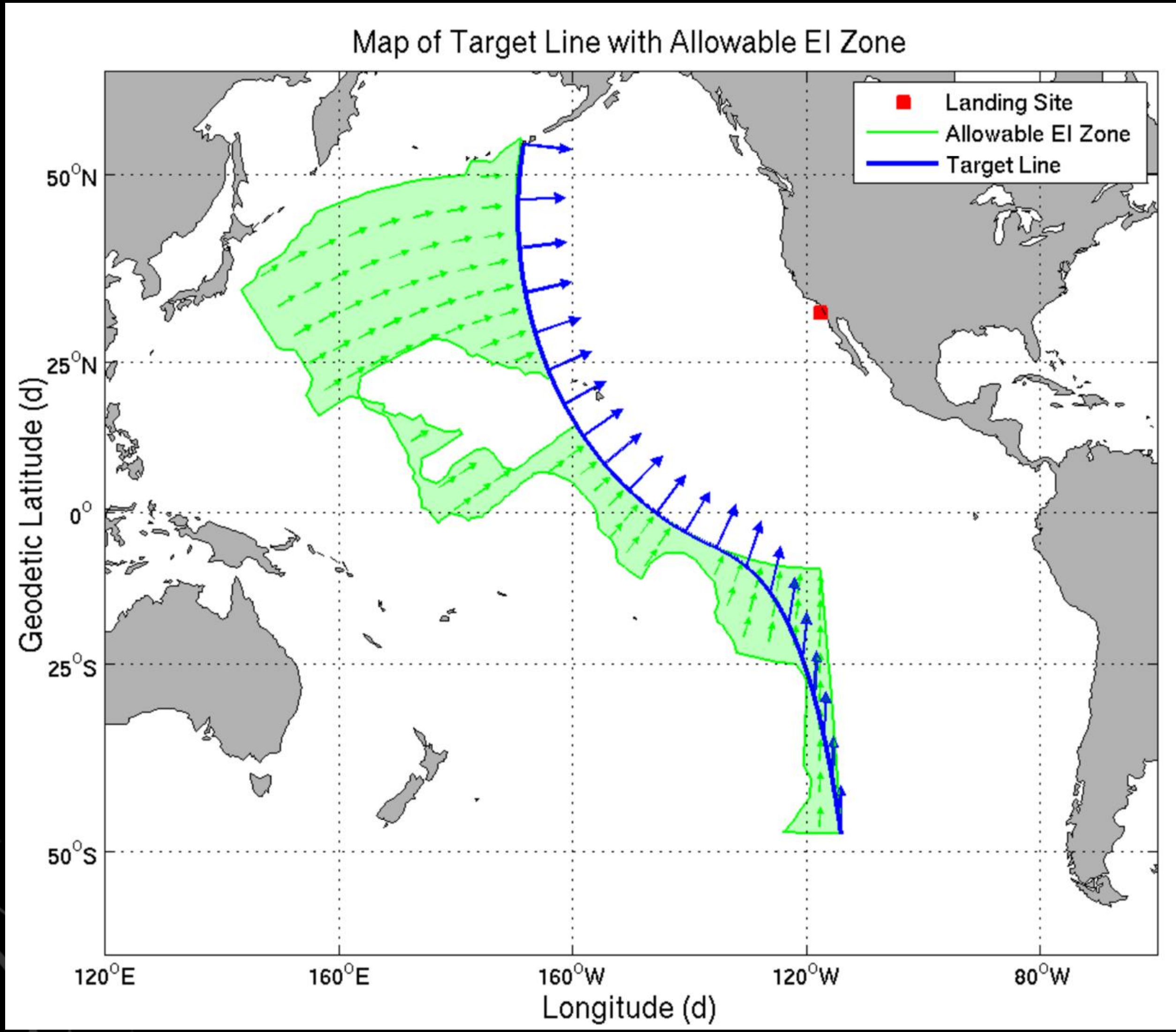
- Vertical Constraints
  - Preserve ballistic entry downmode option
  - Stay within heat shield design limits
  - Provide survivable entry for all Earth return scenarios (26 to 36 kft/s)



TARGET LINE CRITERIA

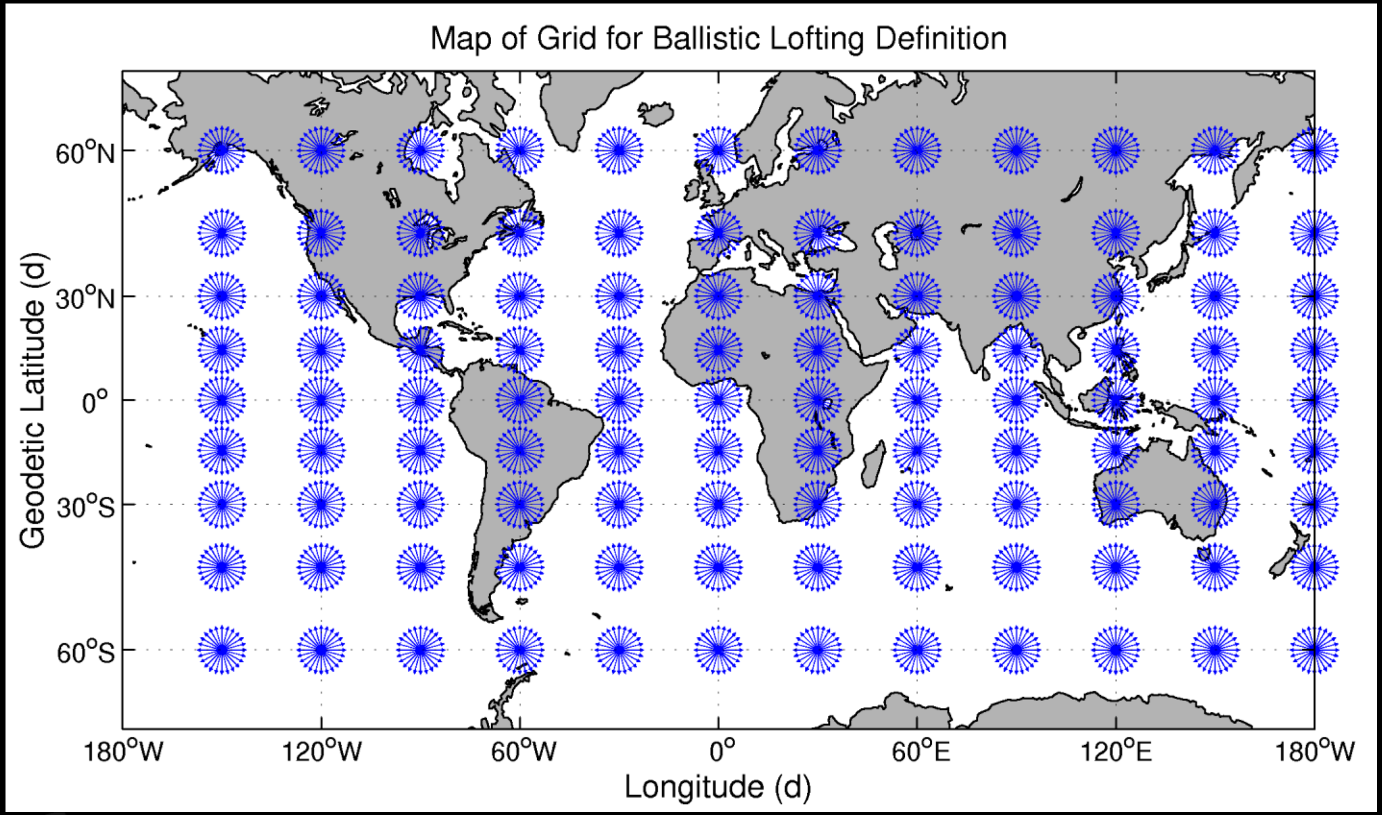
- Minimize the range-to-target when possible
- Choose flight path angle to limit ballistic lofting
- Continuously differentiable
- Functionalized target line in form of polynomial

HORIZONTAL TARGET LINE DEFINITION



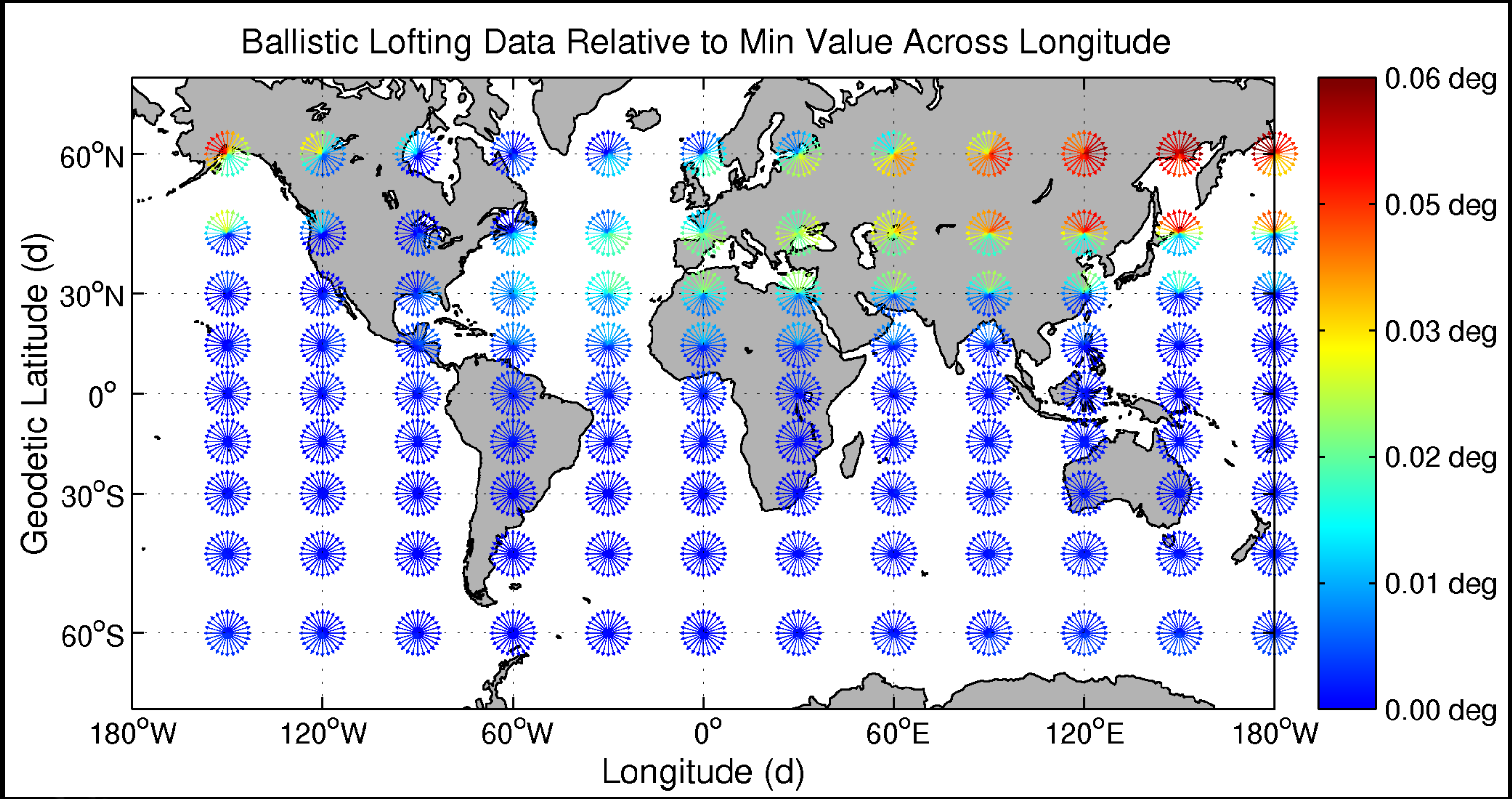
- Spans entire latitude space
- Follows 2500 nmi arc when possible
- No discontinuities
- Invalid zone between 14° and 21.9° latitude

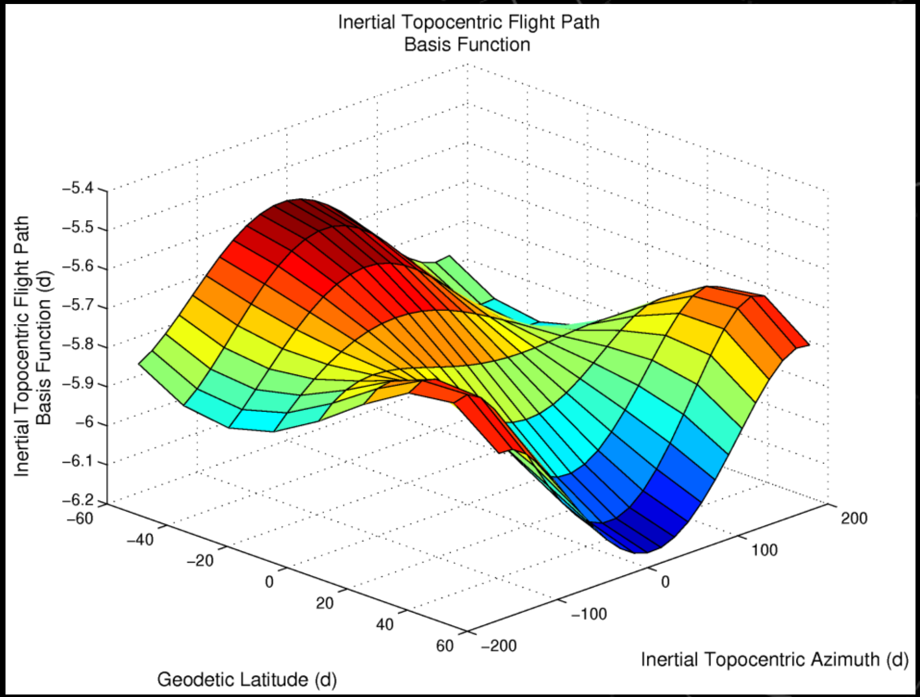
VERTICAL TARGET LINE DEFINITION



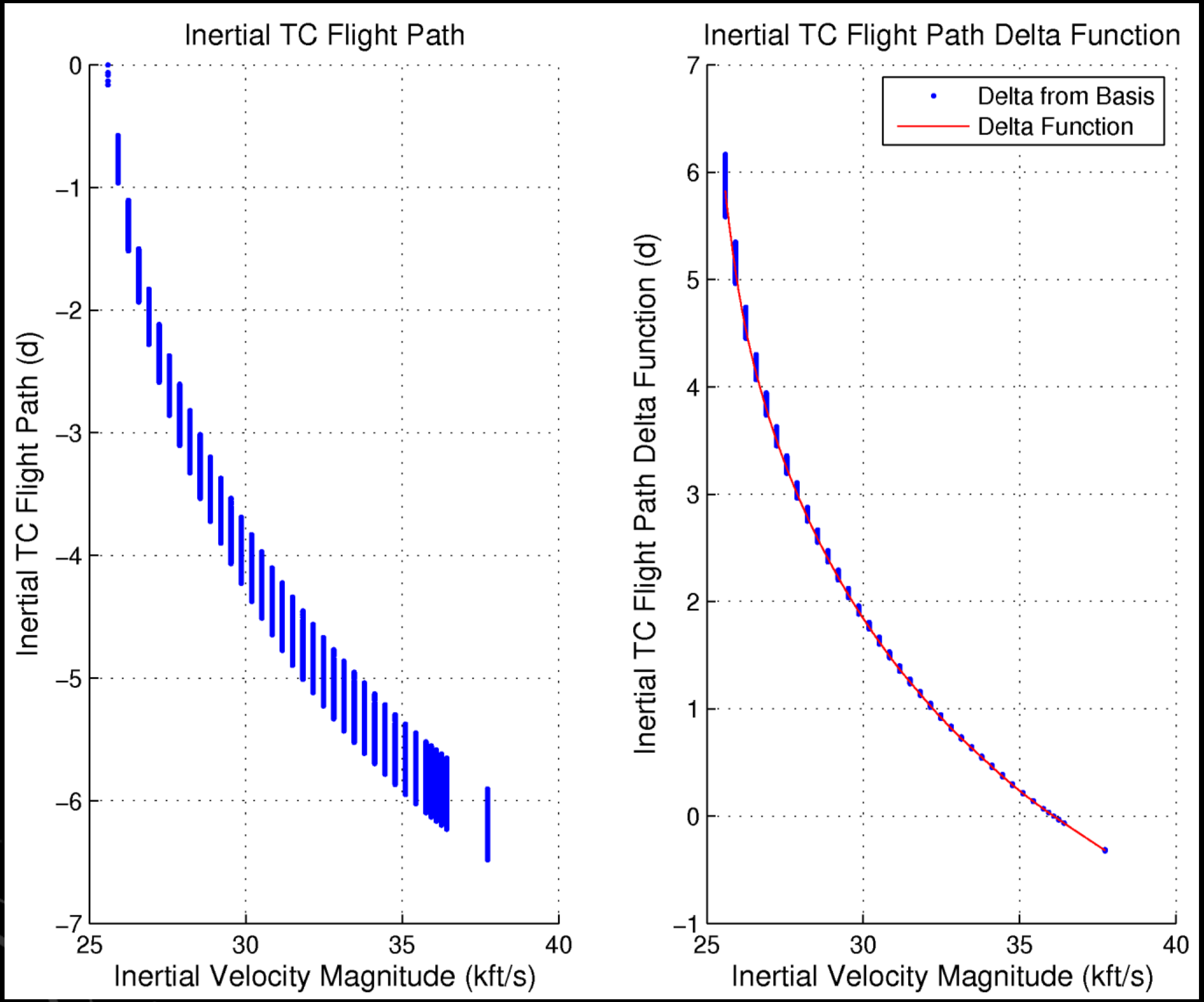
- Define flight path angle that limits ballistic lofting
- Function of:
  - Geodetic latitude
  - Longitude
  - Azimuth
  - Speed

REMOVING DEPENDENCE ON LONGITUDE





DEPENDENCE ON SPEED



- Delta function approximates the change in ballistic lofting flight path angle with respect to speed

FUNCTIONALIZATION IN ONE DIMENSION

- Lagrange interpolating polynomial

$$y(x) = \sum_{j=1}^{N} y_j \phi_j(x)$$

$$\phi_j(x) = \prod_{\substack{m=1 \\ m \neq j}}^{N} \frac{(x - x_m)}{(x_j - x_m)}$$

$y(x)$	=	Approximating polynomial
N	=	Number of nodes
y_j	=	Value of y at x_j
$\phi_j(x)$	=	Set of interpolating functions

- Optimal node spacing at roots of orthogonal polynomials

$$X_{CGL_j} = \cos\left(\frac{(j-1)\pi}{N-1}\right),\ j = 1,2,\dots,N$$

(Chebyshev-Gauss-Lobatto Points)

- Mapping to real domain

$$x_j = \frac{(x_N - x_1)X_{CGL_j} + (x_N + x_1)}{2}$$

x_j	=	j^{th} real EI target line paramater
X_{CGL_j}	=	j^{th} X_{CGL} node point

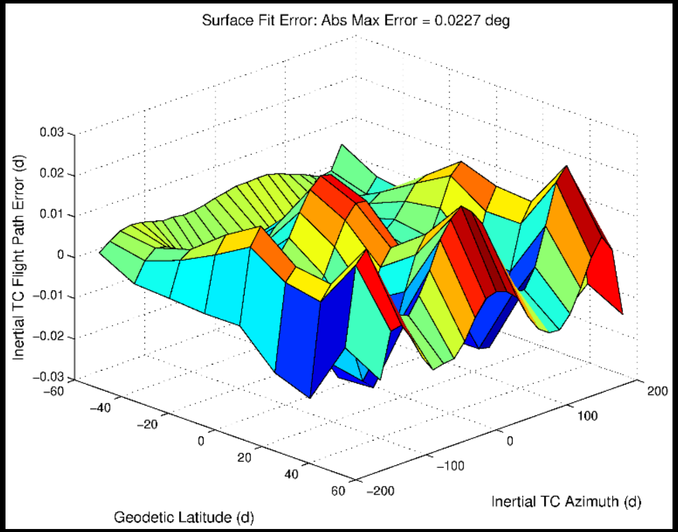
FUNCTIONALIZATION IN TWO DIMENSIONS

- Multivariable Polynomial in Two Variables

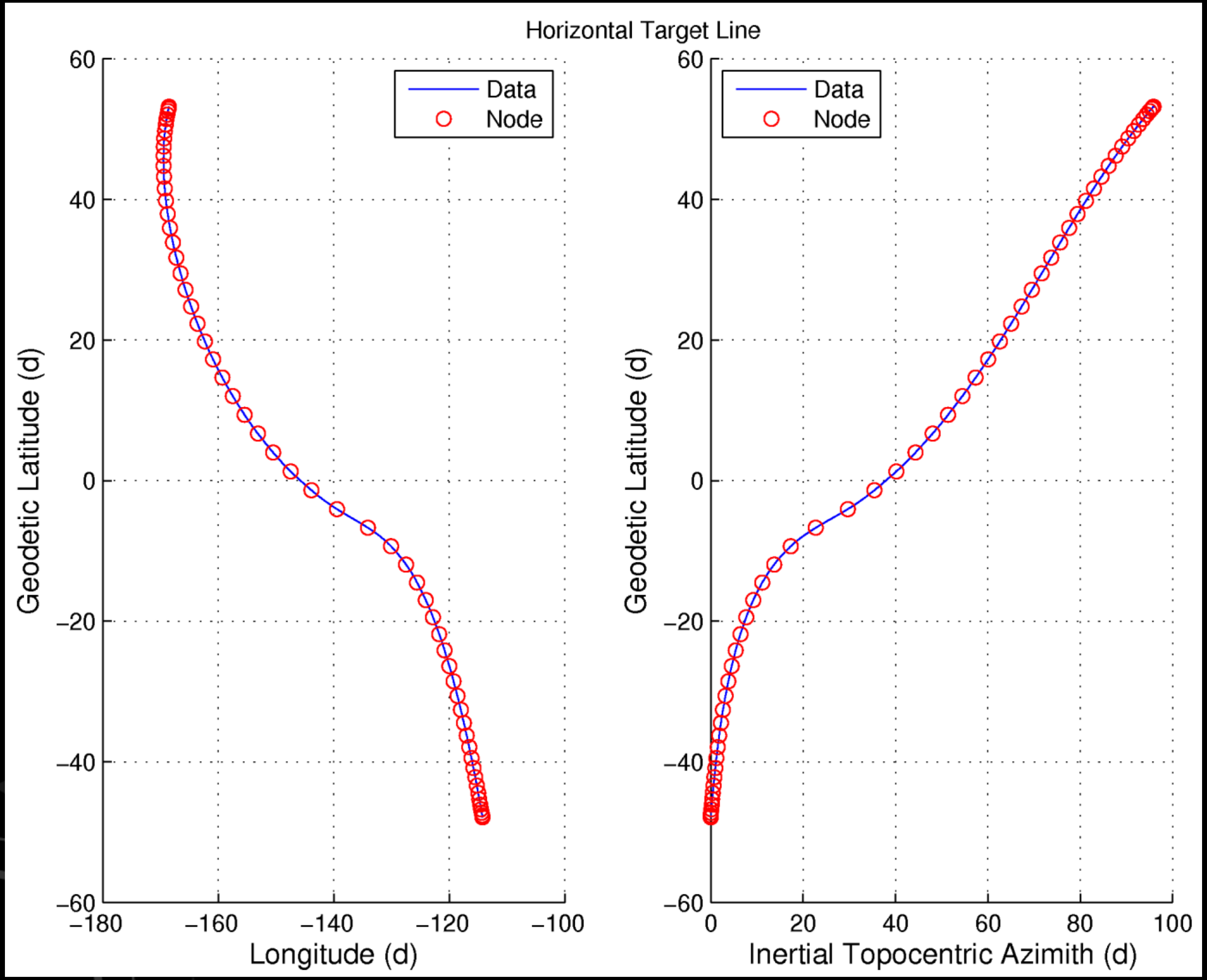
$$z(x,y) = \sum_{i=1}^{N_x+1} \sum_{j=1}^{N_y+1} C_{i,j} x^{(i-1)} y^{(j-1)}$$

$$\begin{aligned} z(x,y) &= \text{Approximating polynomial} \\ N_x &= \text{Highest order of } x \\ N_y &= \text{Highest order of } y \\ C_{i,j} &= \text{Coefficient } i,j \end{aligned}$$

- Flight path angle basis function is fit to this curve using non-constrained optimizer to minimize the norm of the error



HORIZONTAL TARGET LINE

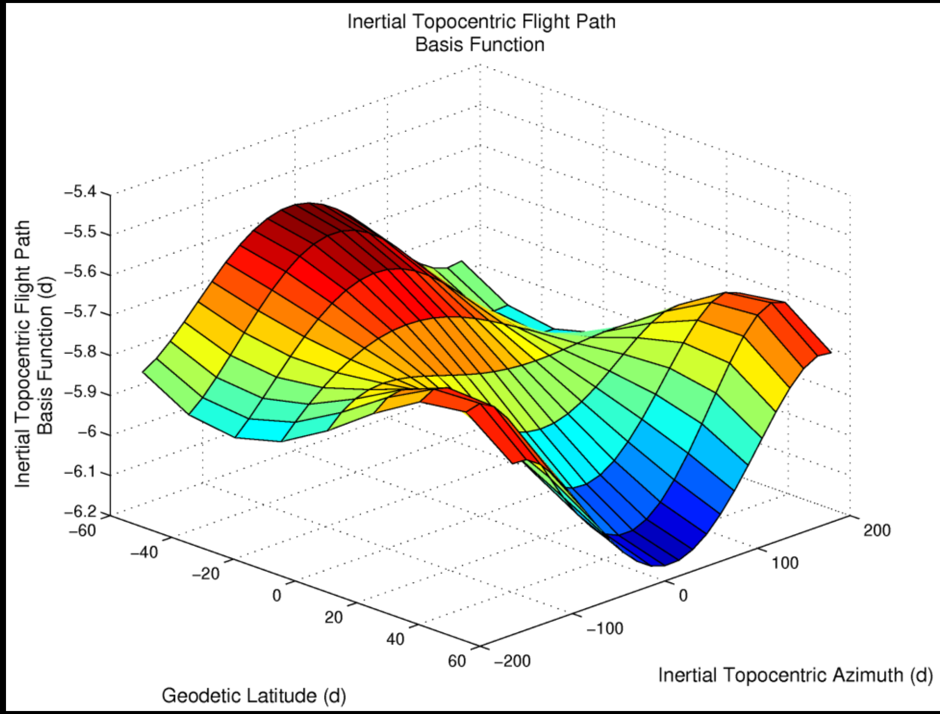


- Independent variable
  - Geodetic latitude
- Dependent variables
  - Longitude
  - Inertial topocentric azimuth
- Lagrange polynomials with 60 nodes

VERTICAL TARGET LINE

Flight Path Angle (FPA) =

Basis Function: *Ballistic lofting FPA at 36 kft/s*



- Multivariable polynomial of order 4,4
- Independent Variables:
  Geodetic latitude
  Inertial topocentric azimuth

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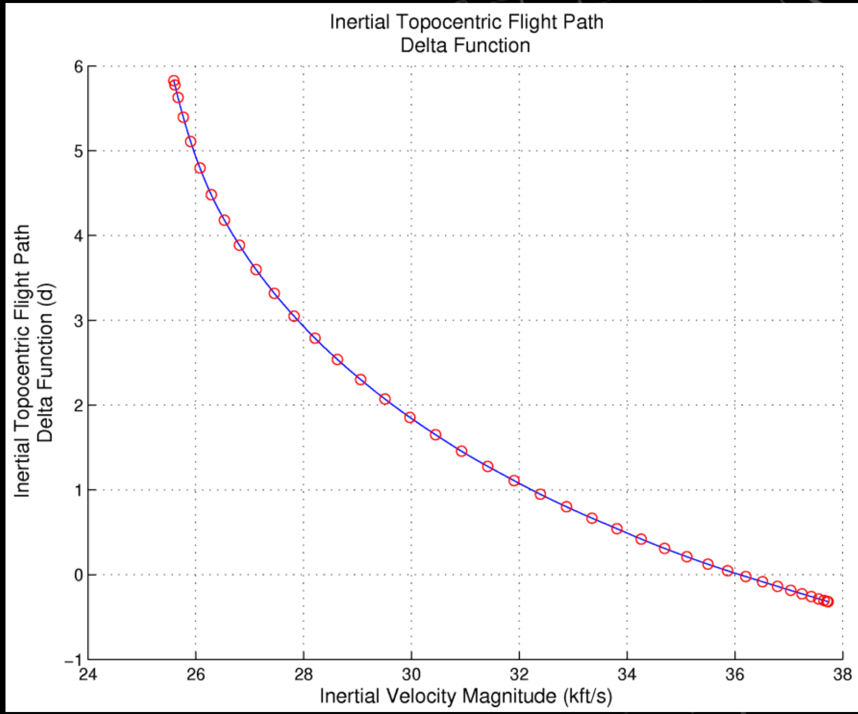
Delta Function: *Difference due to speed*



- Lagrange polynomial with 40 nodes
- Independent Variable:
  Inertial velocity magnitude

SUMMARY

- EI target line functionalizes complex set of entry constraints into a set of polynomials
- These polynomials will be used for both on-board targeting and ground-based trajectory planning