



# Porter

*The Maneuver Visualization Tool*

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# Design Team



Rohan Patel

- Finishing undergrad at CPP (Dec. '20)
- Interested in interplanetary trajectory and maneuver design
- Enjoys aviation, photography, and travel



Jimmy Moore

- A.B.D. Computer Science PhD at U. Utah
- Studying Data Visualization & Human-Centered Design
- <3 synthesizers, music, and baking

How can we support maneuver designers to **more conveniently and effectively** work with MONTE LAMBIC output data?

# Current LAMBIC Data Processing

- Simulation statistics are exported to large text files.

- There are summary and detailed text files ordered by result type.

- Data is sectioned by variable making analysis of multiple variables for a single maneuver less convenient.

Executed Delta-v Magnitude For Each Maneuver:

Maneuver	Mean (m/sec)	Sigma (m/sec)	90%tile (m/sec)	95%tile (m/sec)	99%tile (m/sec)
TCM1	5.984338497124361e+00	3.577981520214469e+00	1.112424419335500e+01	1.289428096218146e+01	1.6758123686850398e+01
TCM2	1.3806492566015126e-01	9.925677736013366e-02	2.574469115281136e-01	2.706615843444796e-01	4.7537030851189737e-01
MGA-3=0	9.934166426245187e-01	1.1084931161221171e-02	1.031698925679085e+00	1.017532406193550e+00	1.0262365913166839e+00
MGA-APR-1	3.924351598128361e-02	1.751339080429280e-02	6.302493472739362e-02	8.045426508310414e-02	7.1558719840089848e-02
MGA-APR-2	1.352473984018922e-02	6.369752544197016e-03	2.2165744917174570e-02	2.540123447277078e-02	3.121596400723873e-02
MGA-CU-1	3.639359309663960e+00	7.720240003025990e-01	4.625889286526790e+00	4.930125616565962e+00	5.480495420936748e+00
MGA-CU-2	4.151853733767459e-02	2.180804237348475e-02	6.974190662696680e-02	8.1530426306746532e-02	1.038337451458173e-01
EGAl-1yearBurn	1.13789785381149e-01	6.48239449964089e-02	2.535371834487011e-01	2.744575780715430e-01	3.604493862599412e-01
EGAl-APR-1	2.224592019530416e-02	1.244256360117010e-02	3.892881834639938e-02	4.638243564898297e-02	6.161397343699715e-02
EGAl-APR-2	1.945982070771165e-02	8.958916737093804e-03	3.151816984517071e-02	3.4507146069427786e-02	4.34869175865823e-02
EGAl-APR-3	1.354599449360169e-02	6.392868527431288e-03	2.199345368429428e-02	2.525367112622163e-02	3.082734862936434e-02
EGAl-CU-1	7.766779345368597e-01	4.089329747238231e-01	1.334387783221923e+00	1.543003298742734e+00	1.979292877238142e+00
EGAl-CU-2	1.202033538009216e-02	7.076736943897456e-03	2.111942450666982e-02	2.577876580159352e-02	3.236333022721765e-02
G00-APR-1	8.4082272475670721e-02	6.215999464162381e-02	7.170679806619265e-01	2.061089442084003e-01	2.703249919471680e-01
G00-APR-2	3.793954989001416e-02	1.789647989547702e-02	6.204567826813941e-02	7.127498309015240e-02	8.91249509111021e-02
G00-APR-3	1.493563160453022e-02	7.132714033184036e-03	2.447126700967377e-02	2.799425102138695e-02	3.496591598247112e-02
JOI	9.151931912476730e+02	4.252513048727852e+00	9.205708635730584e+02	9.220468553283922e+02	9.251739024951637e+02
JOI-CU-1	1.069419938482826e+01	7.157493925106858e+00	2.090853865676001e+01	2.473255698030724e+01	3.292080043294138e+01
JOI-CU-2	1.497162751697134e-01	1.422107828663917e-01	3.219509825930254e-01	4.347084569618375e-01	6.313242906449488e-01
PRM	1.155179157450093e+02	8.272517142374066e-01	1.165824361158911e+02	1.168796426622050e+02	1.174869616645548e+02
PRM-CU-1	1.553591430820663e+00	7.246914661587667e-01	2.546715516424201e+00	2.850635938020802e+00	3.55289766445131e+00
PRM-CU-2	2.348642300044192e-02	1.432537031368258e-02	4.259738319676432e-02	5.09016774334419e-02	7.040980836648519e-02
G01-APR-1	1.627812081419207e-02	8.644571474105255e-03	2.799218480809739e-02	3.289562392481718e-02	4.195711673121103e-02
G01-APR-2	4.0781816978505422e-01	2.990784699573133e+00	6.9902238950989e-01	2.35068072423254e-01	3.818232987767161e-01
G01-CU	5.988323761578244e-01	3.308621291979121e-01	1.036715663898204e+00	1.201551107865090e+00	1.567127600454747e+00
G02-TRG	4.789680494448366e+00	1.853544454778953e-01	4.925683937296758e+00	4.962371186804349e+00	5.047112916981545e+00
G02-APR-1	7.706898496396468e-02	3.992618092203876e-02	1.319399821607687e-01	1.518455322275507e-01	1.93867658905342e-01
G02-APR-2	1.239590737883457e-01	8.23276685163654e-02	2.402535227187991e-01	2.828835417822581e-01	3.775842122119161e-01
G02-CU	6.433666217154063e-01	6.14533317399005e-01	1.745000300800759e+00	2.08425380852748e+00	2.799326075019675e+00
G03-TRG	6.130197648762404e-02	3.605091146880741e-02	1.093991873875907e-01	1.508504622207472e-01	1.744883132166301e-01
G03-APR-1	1.352287319539004e-02	7.217247750524734e-03	2.313977207567744e-02	2.699943257219799e-02	3.565578441943466e-02
G03-APR-2	9.861542056200387e-02	6.600730614088071e-02	1.900394724308597e-01	2.275073104153433e-01	3.02634716274733e-01
G03-CU	8.813870716702850e-01	5.865287512536854e-01	1.633978019001594e+00	1.930474143450040e+00	2.565621566244902e+00
G04-TRG	7.33579362326334e-02	5.939958790142526e-02	1.536108415083391e-01	1.912166236009196e-01	2.678857440393400e-01
G04-APR	4.90819739505459e-02	2.55842513821149e-02	8.206449874721890e-02	5.617003401455118e-02	4.235397474872432e-02
G04-CU	1.4817620915151520e+00	1.112357443717493e+00	3.89808229048069e+00	3.669340973373691e+00	4.706904153089834e+00
E01-TRG	1.953480898236933e-01	1.254488137892850e-01	5.108198668867738e-01	6.337413739197557e-01	8.931675169928272e-01
E01-APR	1.867196406012113e-02	7.084482808215319e-02	3.443080215627262e-02	4.090302712217306e-02	5.81274575171579e-02
E01-CU	9.104453087921569e-01	2.7477573032578209e-01	1.923065950808273e+00	2.265133534910445e+00	3.072968299936553e+00
E02-TRG	2.642490823496390e-01	2.47478790317624e-01	6.0159999628515e-01	7.74675728080526e-01	1.075787114559580e-01
E02-APR	1.991362818928939e-02	1.416528403232746e-02	3.80258454596076e-02	4.684114715757732e-02	6.78948866580394e-02
E02-CU	2.559793690642006e+00	8.702423490375989e-01	3.764076592942703e+00	4.4084100079759911e+00	5.518204912308916e+00
E02-TRG	7.314763685848378e+00	4.720151006021458e-01	7.875361157927793e+00	8.064912784859073e+00	8.433146299715625e+00
E03-APR	2.128472147898962e-01	1.56674200781006e-01	4.3652757800789277e-01	5.132577888721137e-01	6.693226747692521e-01
E03-CU	3.34942194819000e-01	7.777780396424590e-01	1.998358469008490e+00	2.335774272616630e+00	2.925267024092432e+00
E04-TRG	4.634989843255430e-01	2.656412734290359e-01	7.027140846870713e-01	8.730548571323838e-01	1.447553929757552e+00
E04-APR	2.298226938141759e-02	1.692461743781916e-02	4.427563547129428e-02	5.32263862754975e-02	7.42623018219243e-02
E04-CU	7.6345659194769e-01	6.774467105494949e-01	1.725427626868729e+00	1.642563161694226e+00	2.91697341829324e+00
E05-TRG	1.835729870779662e+00	4.867815804389343e-01	2.290933250254757e+00	2.339392263462929e+00	2.532775899646498e+00
E05-APR	5.573369471805709e-02	4.123285656706113e-02	1.182458969167444e-01	1.3680846933699741e-01	1.8966761394680513e-01
E05-CU	2.201799485169046e-01	1.068361851555591e-01	4.064361671425382e-01	5.36331813767456e-01	8.07961668497149e-01
E06-TRG	4.823704979300064e+00	1.198008187651828e-01	4.928529383567868e+00	4.959892842425672e+00	5.097620719371720e+00
E06-APR	2.777048282919037e-01	2.076321564884382e-01	5.66144306033055e-01	6.795040706927018e-01	8.98713042359535e-01
E06-CU	7.56677378223671e-01	3.79938942426491e-01	1.571479871600472e+00	1.910851517047862e+00	2.56515390229260e+00
E07-TRG	4.975342754751751e+00	3.932976220837671e-01	5.363658117804909e+00	5.408455931395144e+00	5.523035802086245e+00
E07-APR	4.461329155666045e-01	8.808051958386858e-02	2.86318552381345e-01	4.313000373829330e-01	4.531194376049450e-01

Maneuver	B.R fixed	B.T fixed	Lin. Time of Flight	S.R fixed	S.T fixed	C3
E24-CU	-2.938928728520182e+00	-1.265750128550097e+02	-4.72865081022951e+01	1.034705549545636e-04	-7.905980724096089e-06	-6.2295967037224905e-05
G02-TRG						
G02-APR-1						
G02						
Ganymede				1.318375632706405e-01	1.318375632706607e-01	
Ganymede				0.024361150186555e-57	0.024361150202613e-57	

# Proposed Maneuver Analysis Solution

Create an intuitive way to access:

- Summary Statistics
- Detailed Result Blocks and M.C. Samples
- Maneuver Design CAPEL Plots

### Europa Clipper

**Mission Data**

Total Maneuvers	218
Total Encounters	68
Start Date	05-NOV-2024 13:40:30
End Date	28-JAN-2034 17:25:15

**Selection Data**

Total Maneuvers	218
Total Encounters	68
Start Date	05-NOV-2024 13:40:30
End Date	28-JAN-2034 17:25:15

**Error Models**

140813 Solar Cruise RCS	
140813 Solar Tour RCS	

Maneuver	Epoch	Encounter	Deterministic (m/s)	Executed (m/s)	$\mu$ -DV	$\Delta V$ Distribution	Percentile Magnitudes	90%	95%	99%	1- $\sigma$	Computed $\Delta V$ (m/s)	95% Exec.
E18-APR	2032-01-11 00:33:17	E18	0	0.143		0.298 0.359 0.517 0.115	0.298	0.359	0.517	0.115	1103.85	1137.61	1168.957
E18-CU	2032-01-17 00:33:17	E18-TRG	0.235	0.253		0.527 0.638 0.861 0.2	0.527	0.638	0.861	0.2	1104.095	1137.663	1169.175
<b>Flyby E19</b> Europa 31-JAN-2032 14:26:12 V-inf: 4.03 (km/s) Flyby Altitude: 25.0 km													
E19-TRG	2032-01-22 22:04:20	E19	7.09	6.93		6.99 7.01 7.05 0.0542	6.99	7.01	7.05	0.0542	1111.171	1164.796	1176.08
E19-APR	2032-01-28 14:26:12	E19	0	0.258		0.526 0.618 0.815 0.186	0.526	0.618	0.815	0.186	1111.171	1165.053	1176.141

Back

### E11-TRG

Epoch 04-SEP-2031 00:49:18 ET

Previous Target (Prev. Encounter) E11

Current Target E11

Next Target E12-TRG

MC Samples 5000

**Magnitude DV**

Deterministic Mag. DV	1.69 m/s
Executed Mag. DV	1.45 m/s

**Executed  $\Delta V$  Magnitude**

Deterministic	1.69 m/s
Mean	1.45 m/s
Sigma	0.341 m/s
$\Delta V$ -99	2.01 m/s

**Model: 190916 Solar Tour 22N**

Type	Error
Fixed Magnitude Sigma	4.670 mm/sec
Proportional Magnitude Sigma	0.330 percent
Fixed Pointing Sigma	3.330 mm/sec
Proportional Pointing Sigma	7.670 mrad

Maneuver  $\Delta V$  Delivery OD-Covariance Capel

### E11-TRG Plots

S-R x S-T

**Spatial Displays**

Show both

Num. Thresholds

Contour Bandwidth ( $\sigma$ )

**Delivery Properties**

Impact Probability	2.8507e-11 %
SMA (km)	7.3968
SMIA (km)	2.1490
Theta (rad)	1.4156
X-Offset (km)	1671.2
Y-Offset (km)	618.06
C3 ( $\text{km}^2/\text{s}^2$ )	15.530
LTOF (sec)	-113.20

**E11 Encounter Plot**

x-y | y-z | x-z

● Deterministic point   ● Monte Carlo output   ■ Deterministic Val.

# How it works

1. Process LAMBIC outputs and supplemental BOA files for the front end
2. API call to load and host data
3. Launch frontend for analysis tasks

# 1. Process LAMBIC Outputs

- Most Stats. Blocks have functions to extract data
- Designed to be used with multiple flight projects and simulations.
- Designed to handle different native data types and result sets automatically.

```
6.417623625726332e-06,
"km/s"
    ],
  },
  "Skipped": null
},
"OD Covariance": "OD Covariance Not Used"
},
"3-TRG": {
  "Maneuver Information": {
    "Porter Format": {
      "MoonFB": "temp. none",
      "Orbit Number": "NN",
      "Maneuver Type": "XXX",
      "Maneuver Number": "NN"
    },
    "Burn Number": 168,
    "Name": "E33-TRG",
    "Frame": "EME2000",
    "Burn Epoch": 2463741.0183310234,
    "Burn Epoch (Cal.)": "23-MAY-2033 12:26:23 ET",
    "Execution Error": "190916 Solar Tour 22N",
    "Skipped": null,
    "Execution Strategy": "Computed",
    "Deterministic Delta-V": {
      "DX": -0.001007743568921487,
      "DY": -0.002082827108445194,
      "DZ": -0.00111287977168529,
      "Magnitude": 0.0025675313533826782
    },
    "Deterministic Cumulative Delta-V": 1.184439529708479,
    "Target Encounter": {
      "Name": "E33",
      "Center": "Europa",
      "Frame": "EME2000",
      "Epoch": 2463748.1422883114,
      "Epoch (Cal.)": "30-MAY-2033 15:24:53 ET",
      "Aimpoint Values": {
        "Conic.bDotFixedR": -1432.9738414987157,
        "Conic.bDotFixedT": -1023.2053448457646,
        "Conic.linearizedTOF": -99.0804539749443,
        "Conic.sDotFixedR": 5.551115123125783e-17,
        "Conic.sDotFixedT": 0.0,
        "Conic.c3": 17.533071814105885
      },
      "Aimpoint Units": {
        "Conic.bDotFixedR": "km",
        "Conic.bDotFixedT": "km",
        "Conic.linearizedTOF": "sec",
        "Conic.sDotFixedR": "",
        "Conic.sDotFixedT": "",
        "Conic.c3": "km**2/sec**2"
      }
    }
  }
}
```

# 2. Porter Server API

## Routes

---

### Implemented Routes

- GET `/api/missions/:missionName/:simName`
  - returns an overview of a mission of a specific simulation (`res_summary.json`)
- GET `/api/missions/:missionName/:simName/:maneuverName/optSamples/preManeuver`
  - returns Pre Maneuver array
- GET `/api/missions/:missionName/:simName/:maneuverName/optSamples/postManeuver`
  - returns Post Maneuver array
- GET `/api/missions/:missionName/:simName/:maneuverName/optSamples/executedDv`
  - returns Executed DV array

### Planned Routes

- GET `/api/missions`
  - returns list of missions that is stored on the Server
- GET `/api/missions/:missionName`
  - returns list of simulations of a mission that is stored on the Server
- POST `/api/missions/:missionName/:simName`
  - upload set of json files that constitutes a single lambic run of a mission

### Testing Routes

Open a web browser of your choice and enter `http://localhost:8080/[SOME_ROUTE]` for any GET endpoint. You should see the server response in the web browser.



# Overarching Design Idea

Analysis is conducted from a high level overview to a low level detailed approach (currently sorted by maneuver).

## Overview

I want to see all maneuvers and their respective encounters between a start and stop time that I define.

### **Maneuver:**

- > Name
- > Deterministic DV
- > Executed Mean DV
- > Executed Sigma
- > Executed Percentiles
- > Cumulative Deterministic DV
- > Cumulative Executed DV

### **Event (Currently B-Plane Encounters for EC data):**

- > Name
- > Flyby Altitude
- > Vinfinity
- > Impact Probability %
- > Ellipse Properties

## Detail (Per Maneuver)

I am interested in the nitty gritty details of a single maneuver. Show me all the data regarding this specific one.

- > Next Encounter
- > Impact
- > Delivery
- > Miss
- > Executed DV Mag Stats.
- > Commanded DV Mag Stats.
- > Error DV Mag Stats.
- > Execution Error
- > OD Covariance
- > Delivery Plots
  - > B-Plane w/ Samples and Ellipses
  - > C3, S\*R, S\*T, LFT distributions
- > Capel Plots
  - > Choose from 29 plot options

# Europa Clipper

## Mission Summary

Total Maneuvers	218
Total Encounters	68
Start Date	05-NOV-2024 13:40:30
End Date	28-JAN-2034 17:25:15

## Selection Summary

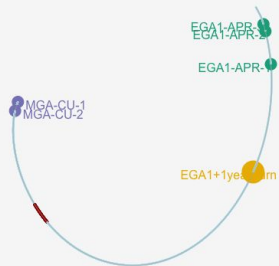
Total Maneuvers	218
Total Encounters	68
Start Date	05-NOV-2024 13:40:30
End Date	28-JAN-2034 17:25:15

## Error Models

140813 Solar Cruise RCS
140813 Solar Tour RCS
150323 Solar Cruise RCS
150323 Solar Tour RCS
150413 Solar Cruise
150413 Solar Tour
150430 Solar Cruise 22N
150430 Solar Cruise 22N x0.5
150430 Solar Cruise 22N x2
150430 Solar Tour 22N
150430 Solar Tour 22N x0.5
150430 Solar Tour 22N x2
190916 Solar Cruise 22N
190916 Solar Cruise 22N x0.5
190916 Solar Cruise 22N x2
190916 Solar Tour 22N
190916 Solar Tour 22N Capability
190916 Solar Tour 22N x0.5
190916 Solar Tour 22N x2
200514 Solar Cruise 22N
200514 Solar Tour 22N
None

## EGA1 Encounter Plot

X-Y Y-Z X-Z



## ΔV Table | Delivery Table

Maneuver			Deterministic (m/s)	Executed (m/s)		Cumulated ΔV (m/s)							
Name	Epoch	Encounter	Maneuver	μ-ΔV	ΔV Distribution	Percentile Magnitudes	90%	95%	99%	1-σ	Determ.	μ Exec.	99% Exec.
TCM1	2024-11-05 13:40:30	MGA	0.575	5.98			11.1	12.9	16.8	3.58	0.575	5.984	16.758
TCM2	2024-12-30 13:40:30	MGA	0	0.13			0.257	0.327	0.475	0.0993	0.575	6.114	17.087
MGA-30	2025-01-28 19:00:05	MGA	0.999	0.999			1.01	1.02	1.03	0.0111	1.574	7.114	18.081
MGA-APR-1	2025-02-17 18:51:53	MGA	0	0.0392			0.063	0.0705	0.0872	0.0175	1.574	7.153	18.127
MGA-APR...	2025-02-22 18:51:53	MGA	0	0.0135			0.0222	0.0254	0.0312	0.00637	1.574	7.167	18.144
<b>Flyby EGA1</b> Earth 01-DEC-2026 21:54:57 V-inf: 11.3 (km/s) Flyby Altitude: 3.01e+3 km													
MGA-CU-1	2025-03-09 18:51:53	EGA1	3.47	3.64			4.63	4.93	5.48	0.772	5.041	10.806	22.369
MGA-CU-2	2025-03-29 18:51:53	EGA1	0	0.0415			0.0697	0.0815	0.104	0.0211	5.041	10.847	22.384
EGA1+1ye...	2026-09-03 16:35:48	EGA1	0.0034	0.114			0.235	0.274	0.36	0.0848	5.045	10.961	22.491
EGA1-AP...	2026-11-01 21:54:57	EGA1	0	0.0222			0.0389	0.0464	0.0616	0.0124	5.045	10.984	22.51
EGA1-AP...	2026-11-21 21:54:57	EGA1	0	0.0195			0.0315	0.0357	0.0434	0.00895	5.045	11.003	22.533
EGA1-AP...	2026-11-26 21:54:57	EGA1	0	0.0135			0.022	0.0253	0.0308	0.00639	5.045	11.017	22.546
<b>Flyby GO</b> Ganymede 10-APR-2030 19:32:01 V-inf: 8.27 (km/s) Flyby Altitude: 200 km													
EGA1-CU-1	2026-12-11 21:54:57	GO	0.272	0.777			1.33	1.54	1.98	0.409	5.317	11.793	23.455
EGA1-CU-2	2026-12-31 21:54:57	GO	0	0.012			0.0211	0.0258	0.0354	0.00708	5.317	11.805	23.471
GOO-APR-1	2029-10-13 06:25:45	GO	0	0.0841			0.171	0.206	0.27	0.0622	5.317	11.889	23.587

Back

### E26-APR

Epoch	19-FEB-2032 22:22:27 ET
Previous Target	(Prev. Encounter)
Current Target	E26
Next Target	C2
MC Samples	5000

#### Magnitude DV

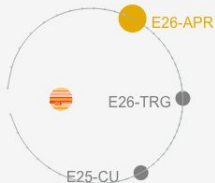
Deterministic Mag. DV	0.00 (m/s)
Executed Mag. DV	0.0384 (m/s)

#### Executed ΔV Magnitude

	(m/s)
Deterministic	0.00
Mean	0.0384
Sigma	0.0307
ΔV-99	0.139

### E26 Flyby Plot

X-Y   Y-Z   X-Z

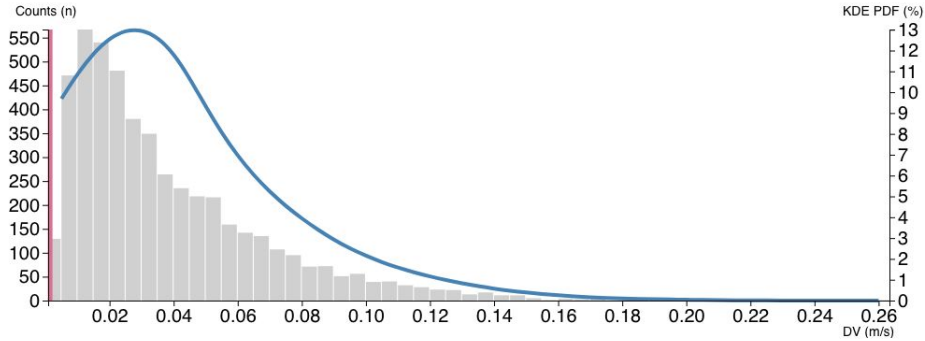


Maneuver DV   Delivery   OD-Covariance   Capel

### E26-APR Executed DV

*Histogram bar height (counts) indicate the number of MC runs evaluating to a given X-axis velocity.*

*The Kernel Density Estimation (KDE) line is an approximation of the underlying continuous probability distribution.*



#### Commanded ΔV

	Magnitude (m/s)	Cumulated (m/s)
Mean	0.0377	977
Sigma	0.0308	7.23
90	0.0811	987
95	0.101	990
99	0.139	998

#### Executed ΔV

	Magnitude (m/s)	Cumulated (m/s)
Mean	0.0384	977
Sigma	0.0307	7.73
90	0.0806	987
95	0.102	991
99	0.139	999

#### ΔV Error

	Magnitude (m/s)	Cumulated (m/s)
Mean	0.00614	9.30
Sigma	0.00271	3.20
90	0.00972	13.6
95	0.0110	15.0
99	0.0139	18.1

Back

## E26-APR

Epoch	19-FEB-2032 22:22:27 ET
Previous Target	(Prev. Encounter)
Current Target	E26
Next Target	C2
MC Samples	5000

### Magnitude DV

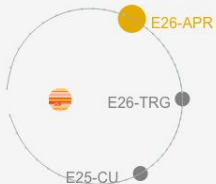
Deterministic Mag. DV	0.00 (m/s)
Executed Mag. DV	0.0384 (m/s)

### Executed $\Delta V$ Magnitude

	(m/s)
Deterministic	0.00
Mean	0.0384
Sigma	0.0307
$\Delta V-99$	0.139

## E26 Flyby Plot

X-Y Y-Z X-Z



Maneuver DV Delivery OD-Covariance Capel

### E26-APR Plots

S-R x S-T

### Spatial Displays

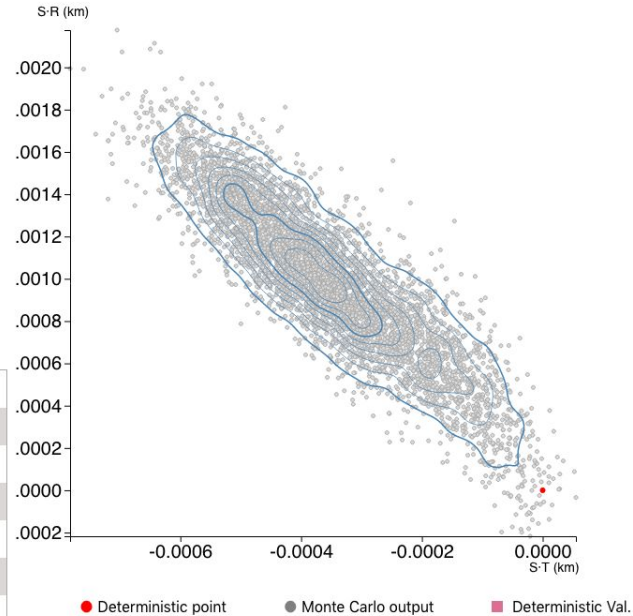
Show hybrid plot

Num. Thresholds

Contour Bandwidth ( $\sigma$ )

### Delivery Properties

Impact Probability	0.0000 %
SMA (km)	1.7185
SMIA (km)	0.33971
Theta (rad)	2.5863
X-Offset (km)	-1048.9
Y-Offset (km)	3994.3
C3 ( $\text{km}^2/\text{s}^2$ )	15.472
LTOF (sec)	-157.59



Initial Response

# Validation

Five hour-long observational studies. Unanimously positive feedback.

**P1:** *Good to see the DV Distributions and overview tables, **previously this was much more difficult***

**P2:** *I really like information being in on place so I **don't have to keep hopping back and forth between different documents***

**P3:** ***This is much easier** than scanning through a text file.*

**P4:** *I usually import data into excel to sort and generate plots, **this does it automatically***

**P5:** *Making tables is usually where I spend most of my time in the post-processing part. Afterwards, you have to show them to other people. **Just this on its own is already an improvement.** And the same for the delivery plots. **It's very easy to share***

# Clear Paths Forward

User feedback is coded and available in Airtable

- Feature requests, modifications, etc.

Integrate with MDNAV and Flight-Ops

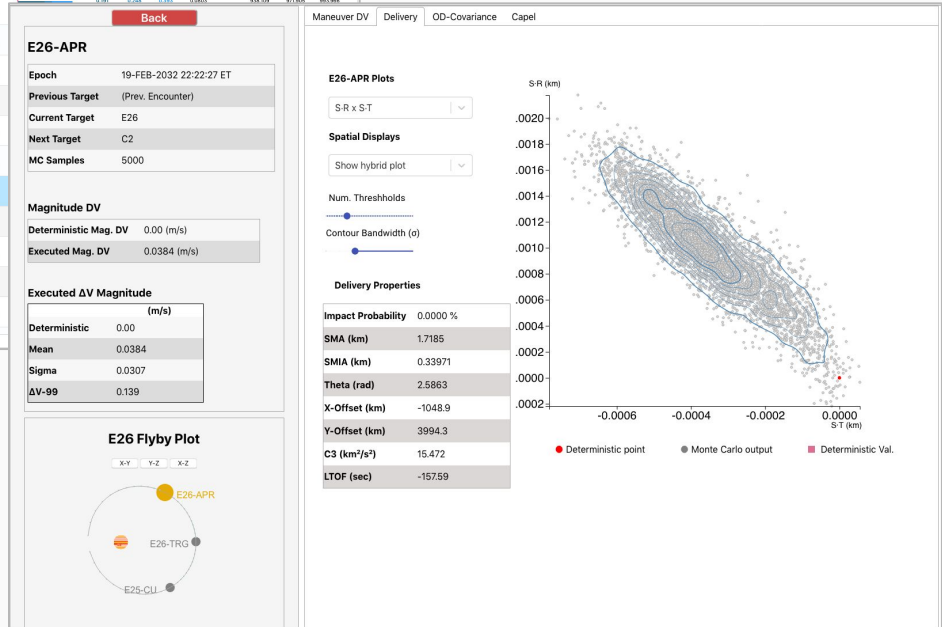
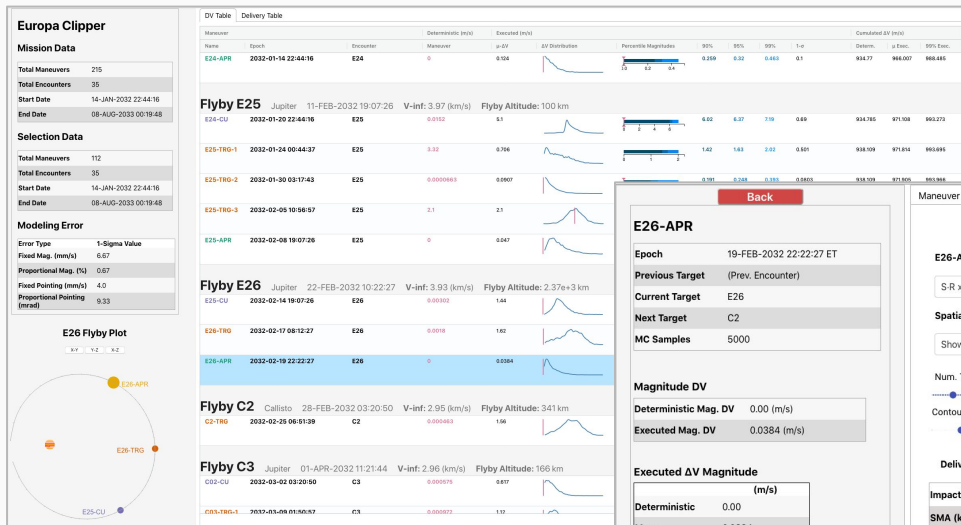
Grow capability over time

	Experience Vector	Feedback Type	Which Page?	Which Component?	A Feedback D
Uyat	Pain Point	Confusion	Overview Page	DV Table	WAs confused
Uyat	Positive	Feedback / Observation	Overview Page	Table Interactivity	Liked the table
Uyat		Feedback / Observation	Overview Page	Table Interactivity	Impact probabi
Uyat		Use-Case	Overview Page	Table Layout	When evaluatin
Uyat	Positive	Feedback / Observation	General Functionality	General Functionality	"Good to see th
Uyat		Strategy	Overview Page	DV Table	Wants to review
Uyat		Strategy	Detail Page	Maneuver DV Panel	Troy checks ex
Uyat	Pain Point	Missing Data	Detail Page	Maneuver DV Panel	Would like to ha
Uyat	Positive	Feedback / Observation	Detail Page	Delivery Panel	Liked the data
Uyat		Missing Data	Detail Page	Delivery Panel	Would like the
Uyat	Pain Point	Feedback / Observation	Detail Page	Capel Plot	Our CAPEL plot
Uyat		Feedback / Observation	Overview Page	Table Layout	Cumulative DV
Uyat		Missing Data	Overview Page	Table Layout	Knowing which
Uyat	Positive	Feedback / Observation	General Functionality	General Functionality	Troy felt positiv
Uyat	Pain Point	Feedback / Observation	Detail Page	Capel Plot	Our implementa
Uyat	Positive	Feedback / Observation	Overview Page	Table Layout	Mar likes the ta
Uyat	Pain Point	Researcher Observation	Overview Page	Table Layout	When reviewing
Uyat	Positive	Feedback / Observation	Overview Page	Table Layout	Mar Liked havin
Uyat	Pain Point	Confusion	Overview Page	DV Distribution plot	Mar initially did
Uyat		Researcher Observation	Overview Page	Table Layout	Mar also did no
Uyat	Pain Point	Feedback / Observation	General UX	General Functionality	Mar's screen cu
Uyat	Pain Point	Feedback / Observation	General UX	General Functionality	Wants to scroll
Uyat	Pain Point	Researcher Observation	Overview Page	Table Interactivity	Table interactiv
Uyat	Positive	Feedback / Observation	General Functionality	General Functionality	Porter's organiz
Uyat	Positive	Feedback / Observation	General UX	General Functionality	Mar really liked
Uyat	Pain Point	Confusion	Overview Page	Table Interactivity	Mar got slightly
Uyat	Pain Point	Confusion	Detail Page	Maneuver DV Panel	Mar was not far
Uyat	Pain Point	Confusion	Detail Page	Maneuver DV Panel	Mar did not un

# Future Development Goals

- Incorporate additional maneuver data products (Capel, Flybys, etc.)
- Perform component-specific user studies as views mature
- Transition to a server-side application
- Extend functionality to other missions, simulation environments.
- Tackle user requests (bulk data export, compare simulations, etc.)





# Thank you for Attending!

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## Mentors

**Jeff Stuart & Sonia Hernandez**  
 Section 392  
 Mission Design & Navigation

**Basak Ramaswamy**  
 Section 397  
 Human Centered Design Group

# Supplemental Slides

what im thinking is like:

intro to who we are (I want this so these people know who i am)

what our goal is

how data is processed

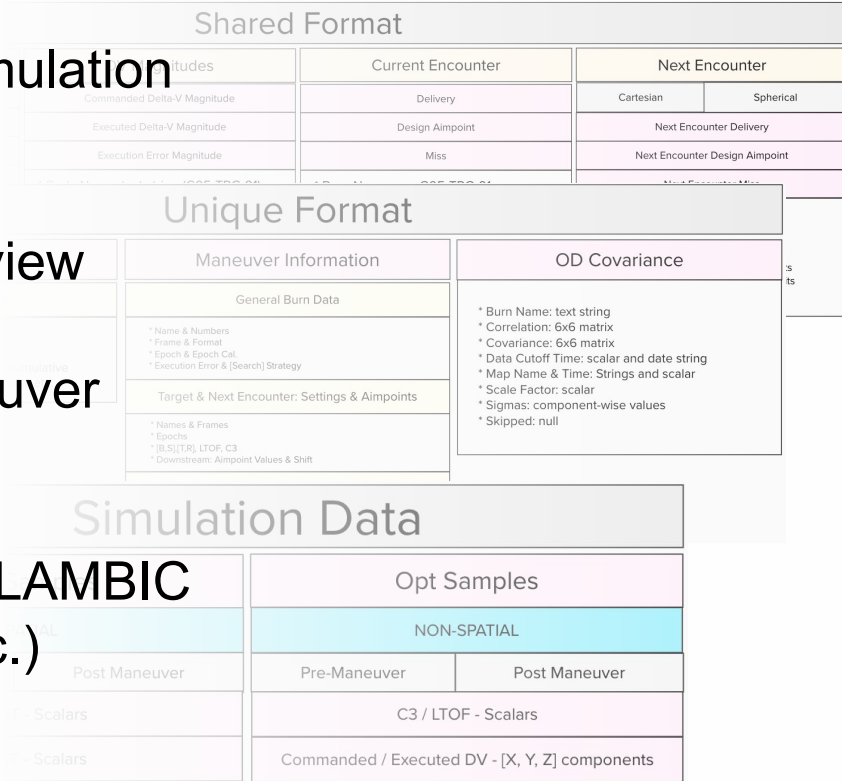
how the UI looks right now

interviews and feedback collection

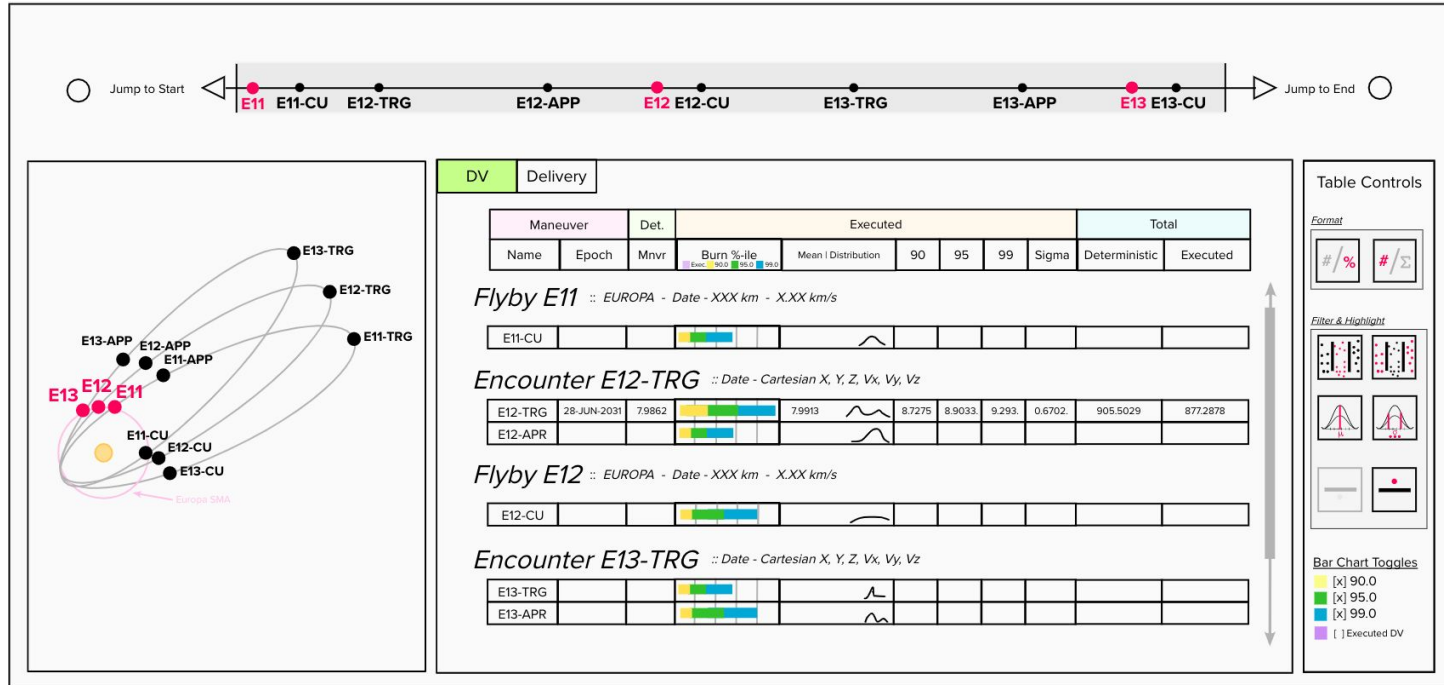
what we hope to see this tool become and how current engineers really like it

# Understanding the Data

- Full JSON conversion for LAMBIC simulation output
- $\Delta V$  and delivery data for simplified review
- Monte Carlo distributions for all maneuver variables available
- External data sources to supplement LAMBIC information (Capel, flyby specifics, etc.)



# Porter Organization: Overview Mode Example



# Porter Organization: Detailed Mode Example

\*CLICK\*

Jump to Start
Jump to End

Back

### E12-TRG

Epoch: 28-JUN-2031 18:16:13 ET

Deterministic Mag.:  
Executed Mag.:

Cumulative Deterministic Mag.:  
Cumulative Executed Mag.:

Current Encounter Target: Europa  
Next Encounter Target: E-13 TRG  
(or other important high level info.)

Delivery	Mnvr. DV	OD Cov.	Capel Plots
<b>Plots</b> <input checked="" type="checkbox"/> B*R B*T <input type="checkbox"/> S*R S*T <input type="checkbox"/> C3 <input type="checkbox"/> LFT			
<b>Plot Tools</b> <input checked="" type="checkbox"/> Show Pre-Maneuver Samples <input checked="" type="checkbox"/> Show Post-Maneuver Samples  <input type="checkbox"/> Plot 1 - Sigma Ellipse <input type="checkbox"/> Plot 2 - Sigma Ellipse <input type="checkbox"/> Plot 3 - Sigma Ellipse  <input type="checkbox"/> Show Density Plots <input checked="" type="checkbox"/> Show Sample Points			
<b>Delivery Properties</b> Impact Probability SMA SMIA Theta X-Offset Y-Offset C3 LFT			

# Internship #1 :: Sept - Dec 2019

Figuring it all out

Accessing and formatting data

Learning what people do & need.

Interviews, workshop, prototype

# Workshop Goals

Identify use cases and pain points in maneuver design.

Brainstorm interactive analysis tools to improve workflows.

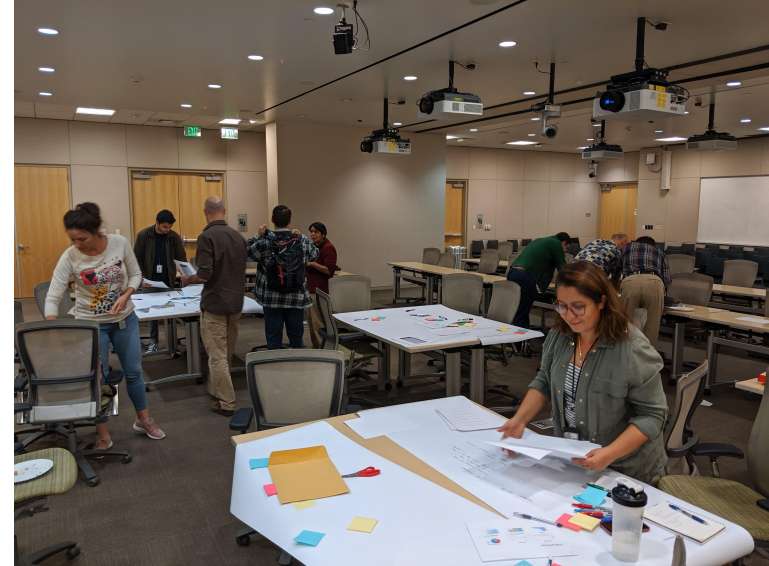
How do you approach the problem at the moment?

Identify current inefficiencies and challenges

How else can this analysis be performed?



**IN 2 HOURS**

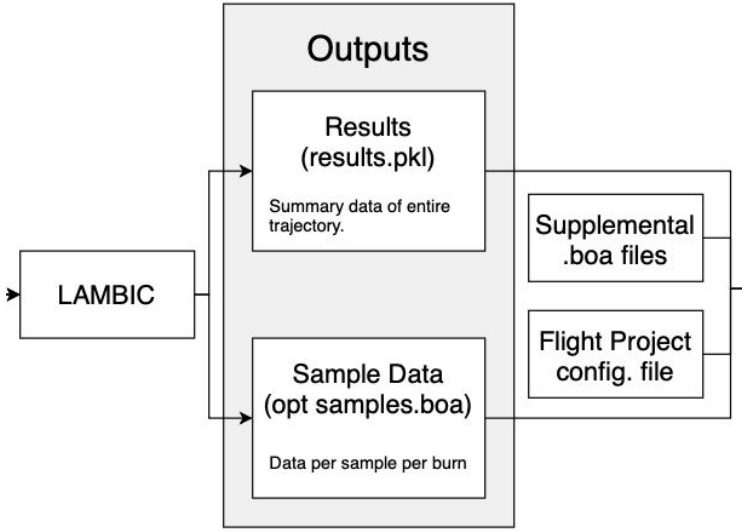


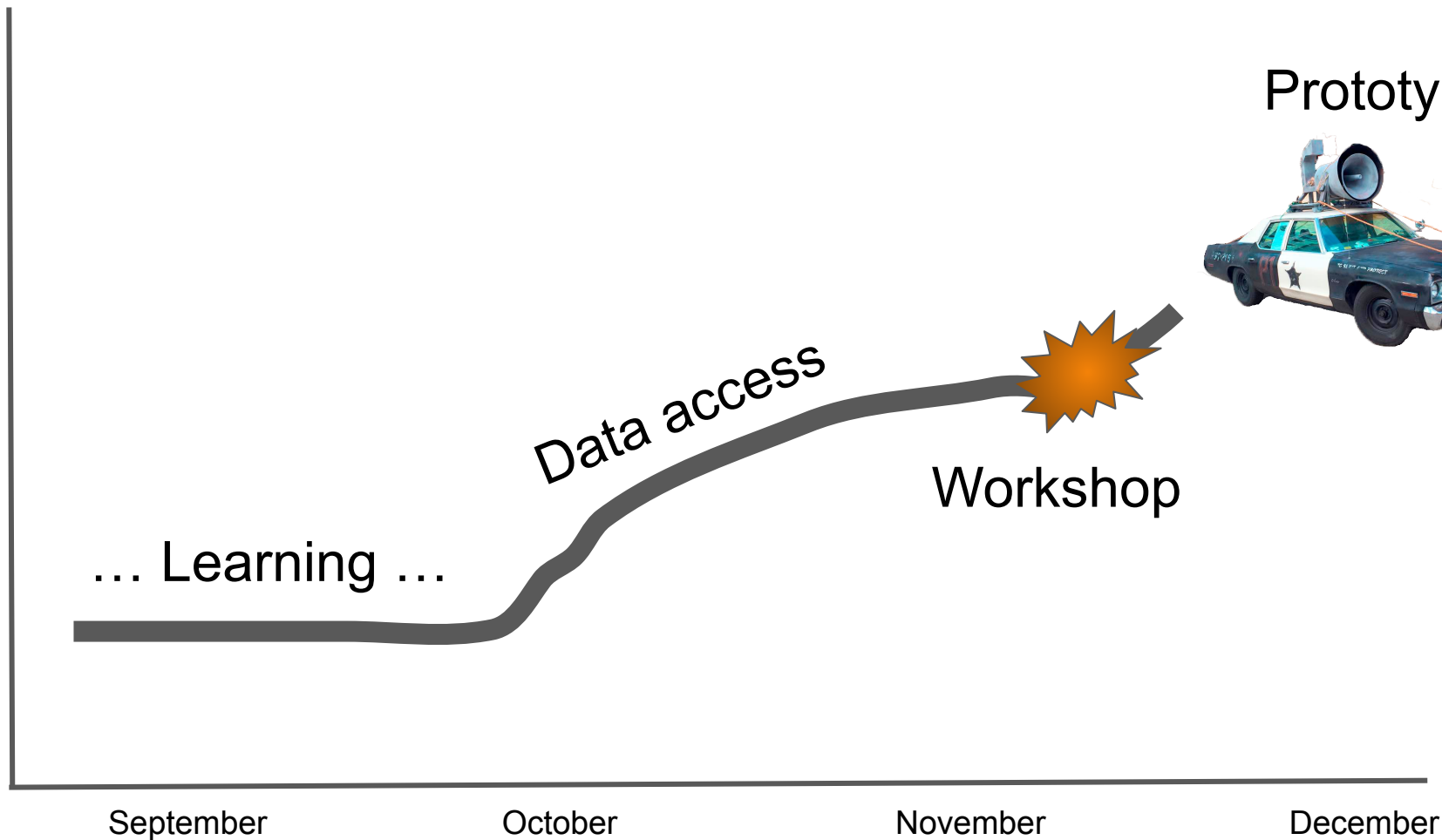


# Three use cases

1. Interactively explore high-level summary statistics
2. Drill down to visualize Monte Carlo simulation data
3. Compare different simulation outputs between conditions

# Characterizing Exploration Tasks





# Internship #2 :: Jun 2020 - Nov. 2020

Finished accessing & formatting data

Understanding what data is available & important (most of the time)

Design interface prototype

Attempts to get feedback on prototype design

Building our technology probe anyway

# Current Project Focus

Create an intuitive and all-inclusive way to access:

LAMBIC Summary Statistics Data

Detailed Result Blocks and M.C. Sample Data from LAMBIC

Capel Plots

# Initial Prototype Design

Initial Prototype

# Europa Clipper

## Mission Data

Total Maneuvers	215
Total Encounters	35
Start Date	14-JAN-2032 22:44:16
End Date	08-AUG-2033 00:19:48

## Selection Data

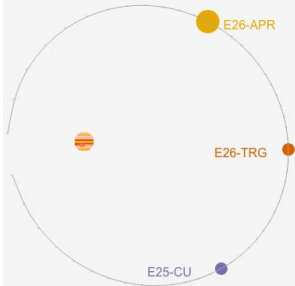
Total Maneuvers	112
Total Encounters	35
Start Date	14-JAN-2032 22:44:16
End Date	08-AUG-2033 00:19:48

## Modeling Error

Error Type	1-Sigma Value
Fixed Mag. (mm/s)	6.67
Proportional Mag. (%)	0.67
Fixed Pointing (mm/s)	4.0
Proportional Pointing (mrad)	9.33

## E26 Flyby Plot

X-Y Y-Z X-Z



## DV Table Delivery Table

Maneuver			Deterministic (m/s)	Executed (m/s)							Cumulated ΔV (m/s)		
Name	Epoch	Encounter	Maneuver	μ-ΔV	ΔV Distribution	Percentile Magnitudes	90%	95%	99%	1-σ	Determ.	μ Exec.	99% Exec.
E24-APR	2032-01-14 22:44:16	E24	0	0.124			0.259	0.32	0.463	0.1	934.77	966.007	988.485

## Flyby E25 Jupiter 11-FEB-2032 19:07:26 V-inf: 3.97 (km/s) Flyby Altitude: 100 km

E24-CU	2032-01-20 22:44:16	E25	0.0152	5.1			6.02	6.37	7.19	0.69	934.785	971.108	993.273
E25-TRG-1	2032-01-24 00:44:37	E25	3.32	0.706			1.42	1.63	2.02	0.501	938.109	971.814	993.695
E25-TRG-2	2032-01-30 03:17:43	E25	0.0000663	0.0907			0.191	0.248	0.393	0.0803	938.109	971.905	993.966
E25-TRG-3	2032-02-05 10:56:57	E25	2.1	2.1			2.11	2.12	2.12	0.00849	940.211	974.007	996.074
E25-APR	2032-02-08 19:07:26	E25	0	0.047			0.0884	0.106	0.137	0.0296	940.211	974.054	996.099

## Flyby E26 Jupiter 22-FEB-2032 10:22:27 V-inf: 3.93 (km/s) Flyby Altitude: 2.37e+3 km

E25-CU	2032-02-14 19:07:26	E26	0.00302	1.44			2.23	2.54	3.16	0.595	940.214	975.498	997.885
E26-TRG	2032-02-17 08:12:27	E26	0.0018	1.62			2.44	2.62	2.92	0.671	940.216	977.122	999.4
E26-APR	2032-02-19 22:22:27	E26	0	0.0384			0.0806	0.102	0.139	0.0307	940.216	977.16	999.462

## Flyby C2 Callisto 28-FEB-2032 03:20:50 V-inf: 2.95 (km/s) Flyby Altitude: 341 km

C2-TRG	2032-02-25 06:51:39	C2	0.000463	1.56			2.28	2.45	2.8	0.563	940.216	978.721	1001.021
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## Flyby C3 Jupiter 01-APR-2032 11:21:44 V-inf: 2.96 (km/s) Flyby Altitude: 166 km

C02-CU	2032-03-02 03:20:50	C3	0.000575	0.617			1.25	1.48	2.06	0.455	940.217	979.338	1001.573
C03-TRG-1	2032-03-09 01:50:57	C3	0.000972	1.12			2	2.29	2.99	0.651	940.218	980.455	1003.177