Final Presentation



Synthetic Generation of a NEO Population

ESRIN, November 18th, 2014





Study Team

Technische Universität Braunschweig Institute of Aerospace Systems



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Motivation

- NEOs could potentially hit our planet
- Depending on their size an impact can produce considerable damage.
- Impacts of large objects are rare, but probability increases with smaller sizes.



https://tallbloke.wordpress.com/2013/03/05/andrew-cooper-were-the-recent-asteroid-flyby-and-russian-meteor-strike-events-linked/





Peru, 2007

- Currently about 11,600 NEOs are known
- 460 NEOs are currently in the risk list
- ➔ About 4% of the known NEO environment



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<u>Overview</u>

- 1. Introduction
- 2. The new synthetic NEO population model:

The way the new NEO model was derived and the current status or work

- 3. Near Earth Object Population Observation Program (NEOPOP): Although more included the focus will be on the Observation Simulation
- 4. Demonstration of the two parts of NEOPOP: Population Generator Observation Simulator
- 5. Conclusion & Discussion







NEOs come predominantly from the main asteroid belt: Initial conditions for residence integrations from known MBOs



Escape routes from the main belt







The new NEO Model Orbits of asteroids at the moment they enter the NEO region



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The new NEO Model Orbits of asteroids at the moment they enter the NEO region



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The new NEO Model NEO orbital distribution from each source



0.002 0.004 0.006 0.008 0.01 0.012 0.014 0.016 0.018 0.002 0.004 0.006 0.008 0.01 0.012 0.014 0.016 0.018 0.02 0.002 0.004 0.006 0.008 0.01 0.012 0.014 0.016 0.018 0.02 0.002 0.004 0.006 0.008 0.01 0.012 0.014 0.016 0.018 0.02 0 0.02 0 0 Relative density Relative density Relative density Relative density

5:2J complex

2:1J complex







The model equation



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Aerospac



The new NEO Model Model fit (G96 data)





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red = predicted, blue = observed

15 15.8 16.8 17.8 18.8 19.8 20.8 21.8 22.8 23.8 24.8 H

red = predicted, blue = observed

red = predicted, blue = observed



Frequency



Model calibrated on G96 data Tested against G96 data



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The new NEO Model Model test (703 data)

1400

1200

1000

80

ĝ

200 •

0 4 8 12 20 28 36

Frequency 80





red = predicted, blue = observed





44 52 60



Model calibrated on G96 data Tested against 703 data



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The new NEO Model Final 7 source model: calibrated to both G96 and 703





red =_predicted, blue = observed

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red = predicted, blue = observed



red = predicted, blue = observed

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Model calibrated on G96+703 data **Tested** against G96+703 data



2500

2000

Frequency 00 1500

1000

200

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The final model: orbital distribution





The final model: H - distribution





Population estimates for D>1km (H<17.5)

Stuart & Binzel (2004): 1090 ± 180 Mainzer et al. (2011): 981 ± 19 Harris (2012, unpublished): 976 ± 30

OUR MODEL:

 987 ± 100







The new NEO Model Final 7 source model: source ratios as a function of H





<u>The new NEO Model</u> NEO albedo model: methods

We define three albedo categories:

Category 1: p_v smaller or equal than 0.1 - flat distribution in the 0.02-0.1 range **Category 2**: p_v larger than 0.1 and smaller or equal than 0.3 – flat distribution **Category 3** p_v larger than 0.3 –exponential distribution: decay by 2.6 every 0.1in p_v

We use 328 NEOs with WISE-measured albedos (H>15 and W3<10). For each object we compute the albedo category. We also compute the probability that the object would have been observed if it had been in either albedo category: B(1), B(2), B(3)

Each survey *s* is caracterized by two parameters: the fraction of objects in cat. 1, 2: $p_s(1)$, $p_s(2)$. Note: $p_s(3)=1-p_s(1)-p_s(2)$. In JFC source we impose $p_s(1)=1$. We fit for the parameters $p_s(1)$, $p_s(2)$ (*s*=1,..6) by maximizing the function

 $k=\sum_{n} Log(\mathcal{P}_{n})$, where *n* is the index of the NEO and

 $P_n = \sum_s P_s(n)(B_n(c_n)p_s(c_n))/(B_n(1)p_s(1)+B_n(2)p_s(2)+B_n(3)p_s(3)),$ $P_s(n)$ being the probability that the asteroid *n* comes from source *s*.



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The new NEO Model NEO albedo model: results & comparison with WISE data





<u>NEOPOP</u> Introduction / Overview

NEOPOP – Near Earth Object Population Observation Program

NEOPOP is written in Fortran as Command-Line Tool (CLT).

CLT consists of four modules in two components:

- Population Generator
 - ➔ Population Generation
 - ➔ Population Analysis
- Observation Generator
 - ➔ Observation Simulation
 - ➔ Observation Analysis

Graphical User Interface (GUI) uses the CLT.







<u>NEOPOP</u> Population Generator

Population Generation:

fictitious model old model new model external population

Population file (MPC,DYS, DES) Physical properties file Population Analysis:

makes use of given or generated population

user-defined analysis and filtering

- Groups & Sources
- Orbital and Object parameters
- Relative distance
- Close-Approach Analysis
- Results generated for 2D/3D/scatter/solar plots





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<u>NEOPOP</u> Observation Simulation: Top-Level Data-Flow



<u>NEOPOP</u> Observation Simulation: The Three Innermost Loops

Stepwise decrease of initial object population:

- Pre-Filter: To skip objects not being able to cross the field of view
- Crossing Analysis: To identify objects that are crossing the field of view
- Detection Analysis: To identify objects that can be detected by the defined sensor system
- ➔ All three parts are implemented in a way for being parallelized in the future.



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<u>NEOPOP</u> Deriving the Crossing Geometry

- Only the objects, which have successfully passed the Crossing Analysis, are analyzed for their crossing of the circular FOV.
- The task is to approximate the objects path within the FOV by a set of snapshots. Linear movement is assumed between two nearby steps.
- For each time step *t*_{step} the time and related coordinates of the sensor and object are stored.





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<u>NEOPOP</u> Data for CCD Exposure

Consideration of integration and gap times:

- Crossing Geoemetry is taken
- Steps in integration time are used directly



- Take valid point of crossing geometry:
- Start and end point of object is being interpolated





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<u>NEOPOP</u> CCD – Signal Modelling

Based on the ...

- ... trace of the object
- ... the pixel dwell times are calculated and
- ... the signal is computed for the center and the surrounding pixels (apply PSF)







<u>NEOPOP</u> Optical Performance Model

Background Sources

Visible light:

- Stars up to user-defined magnitude
- Planets
- Faint starts above user-defined mag.
- Galaxies
- Zodiacal light
- Airglow
- Atmospherically scattered Moon- & Sunlight

Infrared light:

- Stars up to user-defined magnitude
- Planets
- Faint starts above user-defined mag.
- Galaxies
- Zodiacal light
- Interstellar Medium
- Extragalactic Background





<u>NEOPOP</u> Further Features

- Simple Radar sensor model
- Measurement data generation (incl. bias, noise and drift errors)
- Output files contain large set of parameters: Crossing and detected objects, magnitude, SNR etc.
- Output provided per sensor system as well as for overall sensor network
- Skyplots show the objects' positions in the sky for a given time and location.
- Solar system overview plots show object positions, crossings and detections





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<u>NEOPOP</u> Verification by CSS-Campaign Simulation (1/5)

CSS Campaigns of G96:

CSS data (G96&703) from 2005 to 2012 has been used.





Parameters used for the simulation:

Parameter	Value
FOV	1°
Integration Time	30s
Gap Time	30s
FOV per Pixel	0.973"



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<u>NEOPOP</u> Verification by CSS-Campaign Simulation (2/5)





<u>NEOPOP</u> Verification by CSS-Campaign Simulation (3/5)





<u>NEOPOP</u> Verification by CSS-Campaign Simulation (4/5)





<u>NEOPOP</u> Verification by CSS-Campaign Simulation (5/5)





<u>NEOPOP</u> NEOPOP Application: Simulation of Observations from L1

Objective:

- Identify the viability of a NEO-detector on a L1 Space Weather mission
- Compare different potential instruments and setups
- Instrument constraint: max. mass of 3 kg

Setup:

- Observer virtually "in" L1
- Simulation over 14 days

Results (all NEO detections):

- 3 different instruments, 8 different viewing directions
- Longer simulation (1 year, to obtain statistically more significant results) still to be done



Sensor LOS orientations from L1

	FoV [deg^2]	Lim. mag.	1	2 a/b/c/d	3	4	5	Probability object is newly discovered
Sensor 1	5x5	16	0	0/1/1/0	0	0	0	0 % / > 70 %
Sensor 2	22x22	14	0	1 /0/ 1 /0	0	0	0	> 92 % / > 76 %
Sensor 3	140x140	9	0	0/0/0/0	0	0	0	



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NEOPOP Demonstration

ESA NEOPOP - Project: NEOPOP										
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Settings 🗖 🗖	Optical Sensors			- 0						
Run ID neopop PopGen PopAna	Defined Optical Sensors G96 703	Attributes of Selected Optical Sensor								
ObsSim ObsAna		Designator:	703	П. П.						
Population Generator		Operational Mode:	Visible Light	V H						
Basic Settings		Field of View (FOV):	2,850	\$ [deg]						
Population Settings		Integration Time:	30,000	\$ [s]						
Filter Settings		Gap Time:	30,000							
2D Histograms		Minimum Number of Consecutive Detections:	2	<u>♦</u> []						
3D Histograms		Limiting Magnitude:	25,000							
Scatter Plots		Pixel Size:	1,500							
		Number of Pixels per Row:	4096	Č [-]						
Observation Simulator		Scale (Pixel POV):	2,503	↓ ["/pix]						
Basic Settings		Full Width Half Maximum (FWHM):	2,500	(pix)						
Population Settings		Threshold Parameter for Detection:	2.100	↓ [-]						
Concern National		Count Rate Constant for CCD Readout Noise:	11,000	[e-/pix]						
Sensor Network		Count Rate Constant for Dark Noise:	0,000	(e-/pix/s)						
- Ground-based Locations		ISR Filename:	optical.isr							
C Space-based Locations										
- Optical Sensors		Errors								
Radar Sensors		Azimutha	Bias Noise Drift	A (deg)						
2D Histograms		Elevation		<pre> [deg] [deg] </pre>						
3D Histograms	Add Remove			v (acd) v						
Scatter Plots	Optical Sensors Input File									
	obssim.opt									



Conclusion & Discussion Conclusion

Near-Earth Object Population Observation Program (NEOPOP)

- Generation of NEO populations
- Uses new NEO Model, calibrated to recent observation data
- Simulation of NEO population observations
- Uses new Optical Sensor model, taking various background sources into account

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Conclusion & Discussion Discussion

Thank you very much for your attention!

Questions?



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ESA NEOPOP - Project: FP-Demo-0		
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ngs C	Basic Settings (Population Generator)	
Run ID		Comment Lines
орор	Test run of the	
PopGen PopAna	Population Congrator	
ObsSim ObsAna		
Population Generator		Population Generation
Basic Settings	 Generate synthetic NEO population (OLD model) 	If a population and/or at least a cross-reference file is generated:
Population Settings	Generate synthetic NEO population	Compute MOID for PPF Compute collision probability for PPF
Filter Settings		
2D Histograms	 Generate fictitious NEO population 	Random Generator Seed: 1
3D Histograms	Generate Physical Properties File only:	Epoch: 2013-08-28 00:00:01
Scatter Plots	Population File: 01-POPGEN/output/neopop.dvs	
Observation Simulator	Physical Properties File: 01-POPGEN/output/neopop.ppf	
Basic Settings		
Population Settings	Generated/Provided Population File Format: NEODYS_ASTDYS V	
Sensor Network		Population Analysis
Ground-based Locations	Analyse generated population	Analysis Enoch: 2012-05-01 00:00:00
Space-based Locations		
Optical Sensors	Analyse population defined below:	Propagator: SPICE ("PROB2B") V
Radar Sensors	Population File: 01-POPGEN/output/neopop.dys	NEODYS_ASTDYS
2D Histograms	Physical Properties File: 01-POPGEN/output/neopop.ppf	B Z
3D Histograms		
Scatter Plots		Dump Analysed Population
	Dump subset considering filter settings, close approach analysis, e	etc.
	Population File: 01-POPGEN/output/subset.dvs	INFODYS ASTDYS
	Physical Properties File: 01-POPGEN/output/subset.ppf	
		Plot Generation Specifics
	✓ Draw Axes in Solar System Plots	✓ Plot Object Sources instead of Groups in 2D Plots



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Settings 🗖 🗖	Population Settings (Population Generator)				- 0
Run ID					
neopop	Population Generation in General				
PopGen PopAna		5.000			A
ObsSim ObsAna	Min. H-value: Max. H-value:	20.000			
Deputation Consertor	Han I Valaet				V 11
Population Generator	Synthetic Population Generation				
Basic Settings					
Filter Settings	Scaling factor:	1,000			≎ [-]
2D Histograms	Extrapolation Method:	Based on events observed from satellites			✓ [-]
3D Histograms	Class Description in the Description Deliat	2.000			0.10
Scatter Plots	Breaking Point (abs. magnitude):	28 000			
	Slope Parameter from Breaking Point:	5,000			0 1-1
Observation Simulator					
Basic Settings	Fictitious Population Generation				
Population Settings	7755 K- 30-				
Sensor Network	Apolios:	100			0 11
Cround based Lasstians	Amors:	100			○ [*]
Space based Locations	Atens:	100			♦ [-]
Ontical Sensors	🕑 Atiras:	100			○] [-]
Badar Sensors	PHOs:	100			♦ [-]
	Max. distance to Earth (PHOs only):	0,100			(AU)
2D Histograms		Min.		Мах.	
Souther Plate	Semi-Major Axis:	0,050	\$ 5,000		(AU)
Scatter Flots	Eccentricity:	0,000	0,999		♦ [-]
	Inclination:	0,000	260,000		C [deg]
	Arg. of Perihel:	0.000	0 360,000		↓ [deg]
	Mean Anomaly:	0,000	\$ 360,000		(deg)



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Observatoire



NEOPOP Demonstration Backup Backup 5

Run ID		Groups					Si	ources		
op	4 All Groups	cicap				All Sources		arees		
PopGen PopAna	V An oroups		1		1775 AU	V Al Sources			(w)	
ObsSim ObsAna	V Atens		✓ ²	Amors	✓ Atiras	⊡ Hung	ana 🕑 Phocea 🖯	Zinuo Ziu	JIKNOWN	
Population Generator	🗹 Main Belts	🖌 Trojans	∠ 0	Others		🕑 J. 3:1	✓ J. 5:2	/]. 2:1 /	FC	
Basic Settings		Orbital Parar	neters				Relativ	e Distance		
Population Settings		Minimu	m		Maximum	Distance				
2D Histograms	Semi-major Axis:	0,000	0	5,000	(UA)	🗌 relative to Sun:	1,300	0	3,000	0
3D Histograms	Eccentricity:	0,200	0	1,000	♦ [-]	relative to Earth:	0,300	0	2,000	0
Scatter Plots	Inclination:	0,000	0	5,000		_				
Observative Circulators	Longitude of the ascending nod	le: 0,000	0	5,000	C ideal		Close-App	roach Analysi:	5	
Observation Simulator	Argument of Peribels	0.000	~	5.000	(deal	Perform Close Approa	ch Analysis			
Population Settings		0,000		5,000	 Inedi 	Start Epoch:	2013-08-28 00:0	00:01		
Sensor Network	Mean Anomaly:	0,000	0	5,000	○ [deg]	End Epoch:	2020-08-31 23:5	59:59		
Ground-based Locations	Perihel Distance:	0,000	0	5,000	[UA]	Max. Distance to Earth:	0,100			0
Space-based Locations	Aphel Distance:	0,000	0	5,000	[UA]					
Optical Sensors										
Radar Sensors		Object Prop	erties							
2D Histograms	Minimun	ו	Ma	ximum						
3D Histograms	0,000			000	0 [-]					
Scatter Plots	Diameter: 0,000		0 10	000,000	[km]					
	MOID: 0,000		0 1,	000	CIUA]					
	Collision Probability: 0,000		\$ 1,	000	[-]					



	(Population Generator)								
Run ID			Plots						
PopGen PopAna	Axis Type	Log	. Min.		Max.		Cla	ss Wi	dth or Number
ObsSim ObsAna	 Semi-Major Axis [AU] 	v] []	0,000	0	5,000	0	100,000	\$	Number of Classes 🗸
Population Generator	Periapsis [AU]	_	0,000	0	5,000	0	100,000	٢	Number of Classes 🗸
Basic Settings Population Settings	Apoapsis [AU]	~ 1	0,000	0	5,000	0	100,000	0	Number of Classes 🗸
Filter Settings	Eccentricity [-]	_	0,000	0	1,000	0	100,000	٥	Number of Classes 🗸
3D Histograms	Inclination [deg]	<u> </u>	0,000	٥	180,000	0	100,000	٥	Number of Classes 🗸
Scatter Plots	Longitude of Ascending Node [deg]	_	0,000	0	360,000	0	100,000	٥	Number of Classes 🗸
Observation Simulator	Argument of Periapsis [deg]	<u> </u>	0,000	0	360,000	0	360,000	٥	Number of Classes 🗸
Population Settings	✓ Mean Anomaly [deg]	~ U	0,000	0	360,000	0	360,000	٥	Number of Classes 🗸 🗸
Sensor Network	H-Value [-]	~ U	10,000	0	30,000	0	40,000	٥	Number of Classes 🗸
Ground-based Locations	Minimum Orbital Intersection Distance [auj 🗸 🗹	0,001	0	1,000	0	30,000	٥	Number of Classes 🗸
- Optical Sensors	Statistical Collision Probability [-]	<u> </u>	0,000	0	1,000	0	10,000	٢	Number of Classes 🗸 🗸
- Radar Sensors	🕑 Diameter [km]	<u> </u>	0,001	\$	5,000	0	50,000	٥	Number of Classes 🗸
3D Histograms	Distance to Sun [AU]	<u> </u>	0,000	0	5,000	0	50,000	٥	Number of Classes 🗸
Scatter Plots	✓ Distance to Earth [AU]		0,000	0	5,000	0	50,000	٥	Number of Classes 🗸
	Epoch [MJD]	<u> </u>	56000,000	0	56100,000	0	50,000	٥	Number of Classes 🗸



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D									
neopop			Plots						
PopGen PopAna	Axis Type	Log	. Min.		Max.		Clas	ss Wi	dth or Number
ObsSim ObsAna	Semi-Major Axis [AU]	•	0,000	0	5,000	٥	100,000	0	Number of Classes 🗸
Population Generator	Periapsis (ALI)	~	0.000	^	5.000	^	100.000	^	Number of Classes
Basic Settings	Compass [re]	<u> </u>	0,000	~	0,000	~	100,000	Ň	
Population Settings	Apoapsis (AU)	<u>_</u> U	0,000	0	5,000	0	100,000	\$	Number of Classes 🗸
Filter Settings	Eccentricity [-]	v U	0,000	٥	1,000	٥	100,000	٥	Number of Classes 🗸
3D Histograms	Inclination [deg]	•	0,000	٥	180,000	٥	100,000	0	Number of Classes 🗸
Scatter Plots	Longitude of Ascending Node [deg]	~	0,000	٥	360,000	0	100,000	0	Number of Classes 🗸
Observation Simulator	Argument of Periapsis Ideal	~	0.000	0	360.000	0	360.000	0	Number of Classes
Basic Settings						•		•	
Population Settings	Mean Anomaly [deg]	<u> </u>	0,000	0	360,000	0	360,000	0	Number of Classes v
Sensor Network	H-Value [-]	v U	10,000	٥	30,000	٥	40,000	٥	Number of Classes 🗸
Ground-based Locations	Minimum Orbital Intersection Distance [AU]	<u> </u>	0,001	٥	1,000	0	30,000	٥	Number of Classes 🗸
Optical Sensors	Statistical Collision Probability [-]	90	0,000	\$	1,000	٥	10,000	0	Number of Classes
- Radar Sensors	Diameter [km]	· ·	0,001	٥	5,000	٥	50,000	٥	Number of Classes 🗸
3D Histograms	Distance to Sun [AU]	<u>v</u> 0	0,000	٥	5,000	٥	50,000	٥	Number of Classes 🗸
Scatter Plots	Distance to Earth (AU)	• 0	0,000	٥	5,000	٥	50,000	٥	Number of Classes 🗸
	Epoch [MJD]	• 0	56000,000	٥	56100,000	٥	50,000	٥	Number of Classes 🗸



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ct	Summary	Output Category
Output Selection	# # Near Earth Object Population Observation Program	Summary
pGen PopAna	# Population Generator - v1.1.0	
	#	Plot Categories
OSSIM UDSANA	# Generated at 2014-11-14 18:15:01	20 20 0
Plot Subjects	*	20 3D Scatter
i loc subjects	#	
	# Run - TD + neonon	
	t the second sec	
	# Comment: Test run of the	
	# Population Generator	nill
	*	
	* * *	
	#	
	# Parameters used by all models:	
	#	
	# Epoch: 2013 08 28 00 00 01	
	# H_max. 20.00	
	# Scaling factor: 0.100E+01	
	#	
	#	
	# Parameter randomization:	
	# Bandom number generator seed: 1	
	* Aufdom Hamber generator beed, i	
	#	
	# Number of generated objects per orbit type:	
	#	
	# Amors (AMO) • 2538	
	# Apollos (APO) : 3553	
	# Atens (ATE) : 204	
	# Atiras (ATI) : 84	
	# Main Belt Asteroids (MBA) : 0	
	# Jupiter Trojans (JTR) : 0	
	# Other Asteroids (OTH) : 0	
	# Total number of chicate : 6270	
	# TOLAI NUMBER OF ODJECTS : 63/9	







































	Sh Generator)								
Run ID opop			Plots						
PopGen PopAna	Axis Type	Log.	Min.		Max.		Clas	ss Wi	dth or Number
ObsSim ObsAna	Semi-Major Axis [AU]	v	0,000	0	5,000	0	100,000	0	Number of Classes 🗸
Population Generator	Designation (ALM		0.000		(F. 000	•	100.000	•	Number of Classes
Basic Settings		<u> </u>	0,000	0	5,000	0	100,000	0	Number of classes V
Population Settings	Apoapsis [AU]	v U	0,000	٥	5,000	٥	100,000	٥	Number of Classes 🗸
Filter Settings	✓ Eccentricity [-]	~	0,000	0	1,000	0	100,000	٥	Number of Classes 🗸
2D Histograms			-		57 P		-		
3D Histograms	Inclination [deg]	<u> </u>	0,000	0	180,000	0	100,000	¢	Number of Classes v
Scaller Pibls	Longitude of Ascending Node [deg]	v U	0,000	٥	360,000	٥	100,000	٥	Number of Classes 🗸
Observation Simulator	 Argument of Periapsis [deg] 	<u> </u>	0,000	٥	360,000	٥	360,000	٥	Number of Classes 🗸
Population Settings	Mean Anomaly [deg]		0,000	٥	360,000	٥	360,000	٥	Number of Classes 🗸 🗸
Sensor Network	✓ H-Value [-]	v U	10,000	٥	30,000	٥	40,000	٥	Number of Classes 🗸
Ground-based Locations	Minimum Orbital Intersection Distance [AU]	~ ~	0,001	٥	1,000	0	30,000	٥	Number of Classes 🗸
Optical Sensors	Statistical Collision Probability [-]	- 	0,000	0	1,000	0	10,000	0	Number of Classes
Radar Sensors	✓ Diameter [km]	~ ~	0,001	٥	5,000	٥	50,000	٥	Number of Classes 🗸
3D Histograms	 Distance to Sun [AU] 	<u>•</u> 0	0,000	٥	5,000	٥	50,000	٥	Number of Classes 🗸
Scatter Plots	 Distance to Earth [AU] 	• 0	0,000	٥	5,000	٥	50,000	٥	Number of Classes 🗸
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Observation Simulator	2	[Argument of Periapsis [deg]	<u> </u>	0,000	0	360,000	0	360,000	٢	Number of Classes 🗸 🗸
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	0	Statistical Collision Probability [-]	<u> </u>	0,000	0	1,000	٢	10,000	\$	Number of Classes
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Scatter Plots	\leq	[Distance to Earth [AU]	<u> </u>	0,000	٥	5,000	0	50,000	٥	Number of Classes 🗸 🗸
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Sensor Network		General Switches				Additional Dat	a Dumps	
- Ground-based Locations								
Space-based Locations	Perform Pre-Filtering			🕑 Dump meas	urement data fo	or detected objects		
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Scatter Plots Skyplots Plot Lines					3D Histograms
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Output Selection	Differential Cumulative Reverse Cumulative	Summary	
PopGen PopAna ObsSim ObsAna	Test run of the Population Generator	Plot Categories	
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S01: G96		P03: ECC vs. ECC P04: INC vs. INC	
		P05: LAN vs. LAN	
	Earth	P07: MANO vs. MANO	
	0 Mars	P08: H vs. H P09: TCA vs. TCA	
	-2 - Detections	P10: TCA_RNG vs. TCA_RNG P11: TCA_RRT vs. TCA_RRT	
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Population Generator		Analysis Mode					
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Population Settings	Number of steps in FOV (Geometry Filter): 400	Propaga	tor: SPICE ("PRO	OB2B")	~		
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Population Settings Biter Settings 2D Histograms 3D Histograms	Analysis Start Epoch: 2012-04-01 00:00:00 Duration of Observation: 0 ♦ 0 ♦	s Epoch 0 ♀ 0 ♀ 0 ♀ [YY MM DD hh mm ss]
Scatter Plots Observation Simulator Basic Settings Population Settings Sensor Network	Number of Monte-Carlo Runs: Seed for Random Number Gene Number of steps in FOV (Geom	dered: 10,100
Ground-based Locations Space-based Locations Optical Sensors Radar Sensors 2D Histograms 3D Histograms	Perform Pre-Filtering Perform Crossing Analysis Consider Light Travel Time Consider Tropospheric Refraction	✓ Dump measurement data for detected objects Max. number of measurements to be generated: 3 ♀ [-]
Scatter Plots	Skyplots Create Skyplots Grid Size: 5,000 (deg) Solar System Plots V Draw Solar System Plot Axes	Plot Lines Line Type Line Width Name Population 1 1 Basic Population Crossings 2 1 Crossing objects Detections 3 1 Detected objects













