

# Group 17

## Agent-based Modelling (ABM)

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### Simulating Societal Collapse in Multi-Generational Space Travel

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# Existing Literature

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... about space settlements and survival:

- “Computing the minimal crew for a multi-generational space travel towards Proxima Centauri b”  
Marin & Beluffi (2018)
- “Minimum Number of Settlers for Survival on Another Planet”  
Salotti (2020)
- “Should and could humans go to Mars? Yes, but not now and not in the near future”  
Szocik (2019)
- “Can Deep Altruism Sustain Space Settlement?”  
Haqq-Misra (2019)

*“... shows that ethical and social virtues, not current technological and medical threats, are the biggest risk for success of the mission.”*  
by Haqq-Misra (2019) cited in Szocik (2019)





# Motivation

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- Observe: complex social behaviour.
- Complex task: sustaining a society with limited resources for multiple generations
- Consider: social / human factors

Take Examples from Lecture:

- *Dating Choice Model* by Kalick and Hamilton (1986)
- *Simulating Irrational Human Behavior to Prevent Resource Depletion* by Sircova, Karimi, Osin, Holme, Strömbom (2015)
- Granovetter Threshold Model (1978)
- Opinion Dynamics



# Base Model

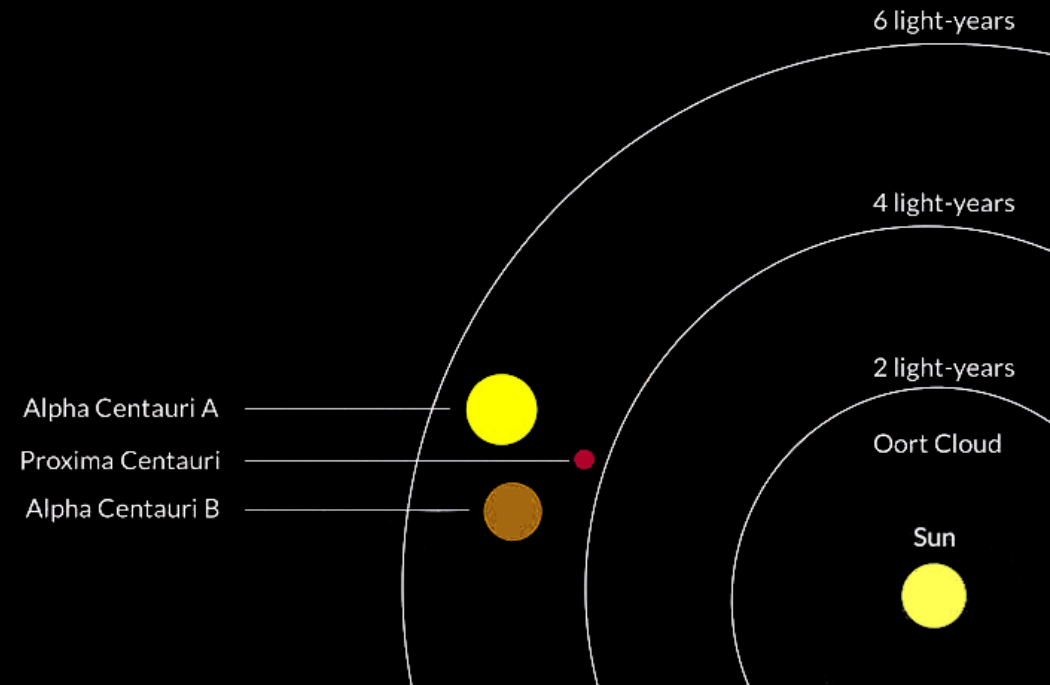


Found ABM model with mating logic but without any **selectiveness** (apart from simple checks) or **irrational behaviour**:

- Model initially based on an astrophysics paper [1]
- ABM approach based on **Netlogo model** [2]
  - Simulation of long-distance space flight
  - contains realistic data
  - parameters set based on research

[1] "Computing the minimal crew for a multi-generational space travel towards Proxima Centauri b" by Marin & Beluffi (2018)

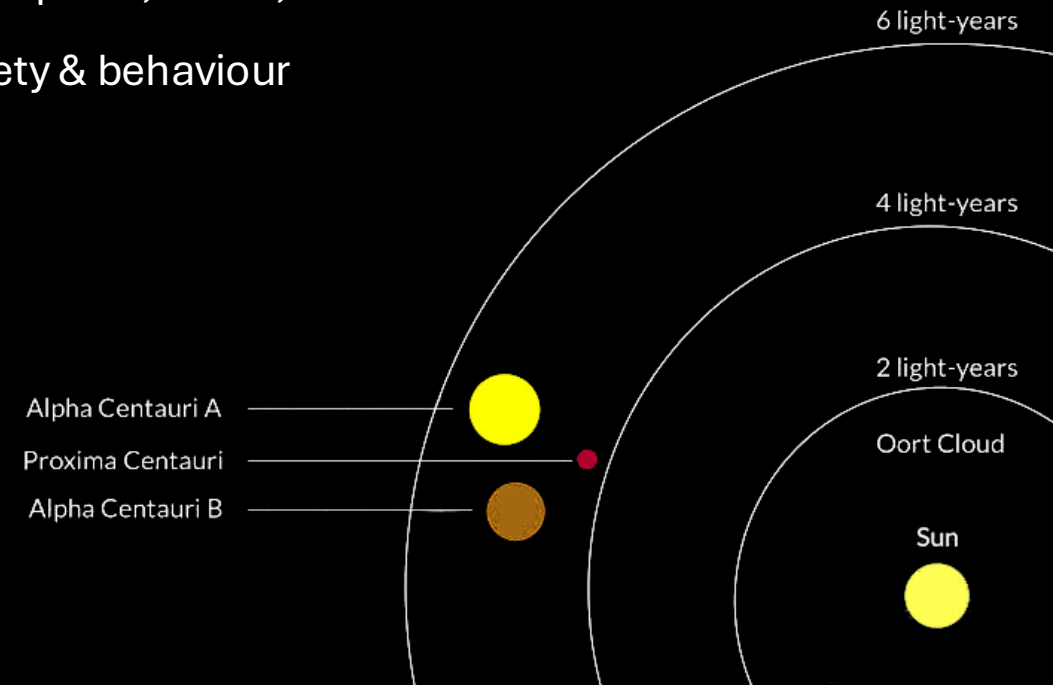
[2] "Simulation of a long-distance space flight" by Sommer & Thorsten (2019)



# Base Model



- Base Model simulates **life on spaceship**
- **Agents**: male & female, movement, mating, pregnancy
- **Parameters**: crew size, fertility, age, mating behaviour
- **Observation mechanics**: population over time, accidents, crew demographics, births, deaths
- **Assumptions**: infinite resources, no maintenance needed, simple society & behaviour
- **Environment**: safety zones on ship, accidents occur
- **Mission Completion Check**:
  - Year 6,300 is reached
  - overcapacity
  - or **extinction**



# Analysis 1

Base Model (society survives with default parameters)

## Initial parameters:

initialCrewSize 100 people

☐ On simulateMonthsInsteadOfDays

## Crew's initial age:

initialAgeFemales 20 years

initialAgeMales 20 years

initialAgeStdDeviation 22 years

## Max. age:

maxAgeFemales 85.0 years

maxAgeMales 79.0 years

ageStdDeviation 15 years

## Crew's bio parameters:

infertilityFemales 10 %

infertilityMales 15 %

maxChildrenPerFemale 2.0 children

maxChildrenStdDeviation 0.5

startAgePermittedMating 35 years

endAgePermittedMating 40 years

☐ On useDynamicPermittedMating

## Females's bio parameters:

meanAgeMenopause 48.81 years

ageMenopauseStdDeviation 3.9 years

setup

go

## Current Year

6300

## Males' statistics:

# males 211

# males (infertile) 29

mean age males 43.68

## Females' statistics:

# females 216

# females (infertile) 19

mean age females 46.48

## Crew's statistics:

mean age crew 45.08

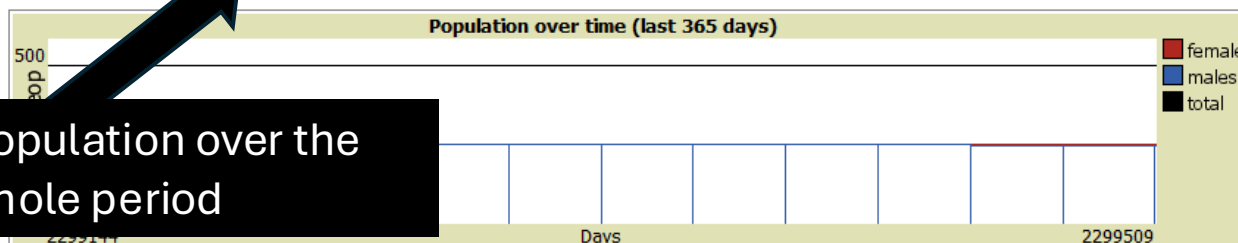
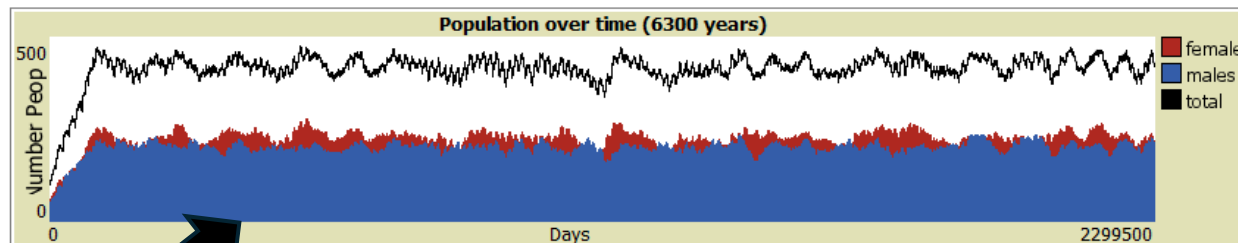
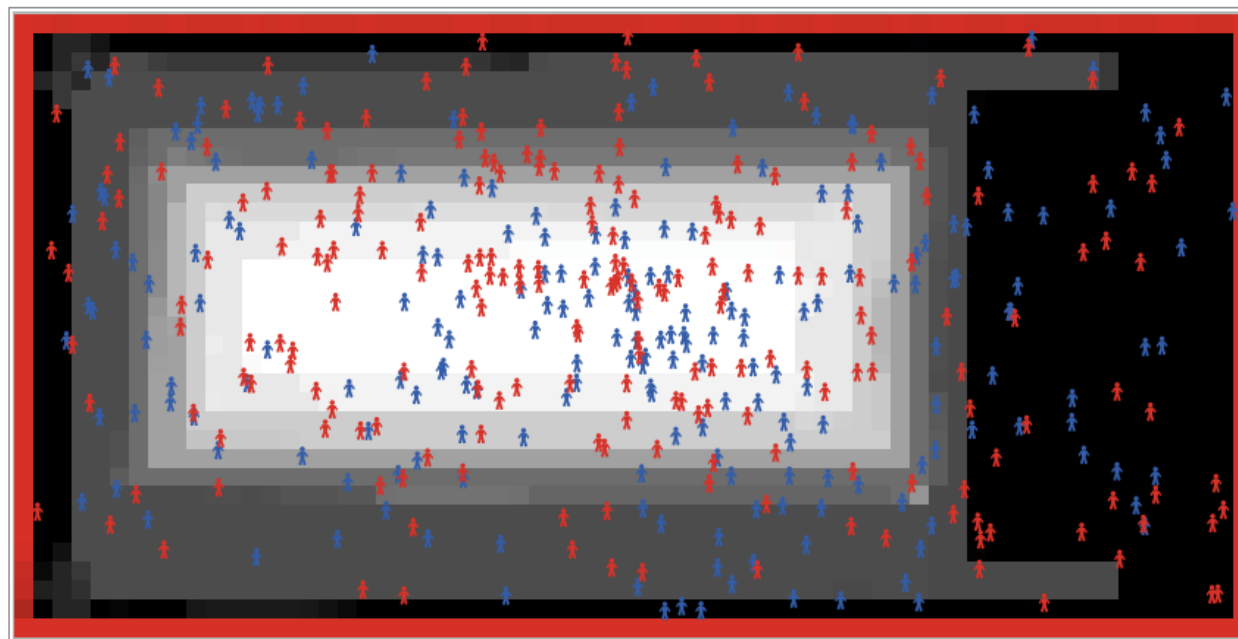
# accidents 743

# deaths caused by accidents 127

# deaths 31701

# pregnancies 5

# births	# females	# males
32028	16446	15582



After the mission ended, the reason why this was the case is given here:

The mission was successful: survivors reached the distant planet.

Stable population over the whole period

# Extended Model: with Selectiveness logic



- NEW: Determine the probability of mating
- Process simulates a more realistic social interaction
- Attractiveness-based mate selection simulates mutual consent
- Attractiveness value assigned randomly
  - at birth of each agent (random 0-10)
- When two agents meet:
  - calculate individual differences in values
  - The smaller the difference, the higher the accept probability (%)
  - If attractiveness difference is large, the probability of mating decreases, leading to more rejections.

## Research Question:

*After the introduction of selective dating preferences, at what difference threshold in polarizing view values does the society go extinct because it cannot sustain itself any longer?*



# Analysis 2

Extended Model: Base Model that includes selectiveness



Initial parameters:

initialCrewSize 100 people

☒ On simulateMonthsInsteadOfDays

Crew's initial age:

initialAgeFemales 20 years

initialAgeMales 20 years

initialAgeStdDeviation 22 years

Max. age:

maxAgeFemales 85.0 years

maxAgeMales 79.0 years

ageStdDeviation 15 years

Crew's bio parameters:

infertilityFemales 10 %

infertilityMales 15 %

maxChildrenPerFemale 2.0 children

maxChildrenStdDeviation 0.5

startAgePermittedMating 35 years

endAgePermittedMating 40 years

☒ On useDynamicPermittedMating

Females's bio parameters:

meanAgeMenopause 48.81 years

ageMenopauseStdDeviation 3.9 years

setup

go

Current Year

6300

Males' statistics:

# males 199

# males (infertile) 41

mean age males 37.49

Females' statistics:

# females 198

# females (infertile) 18

mean age females 41.09

Crew's statistics:

mean age crew 39.29

# accidents 777

# deaths caused by accidents 128

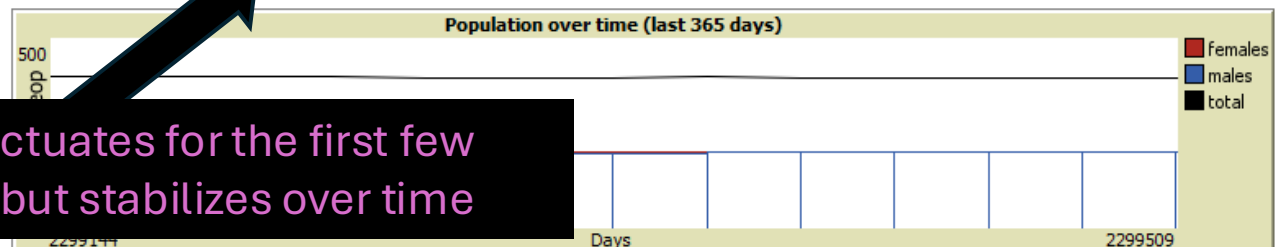
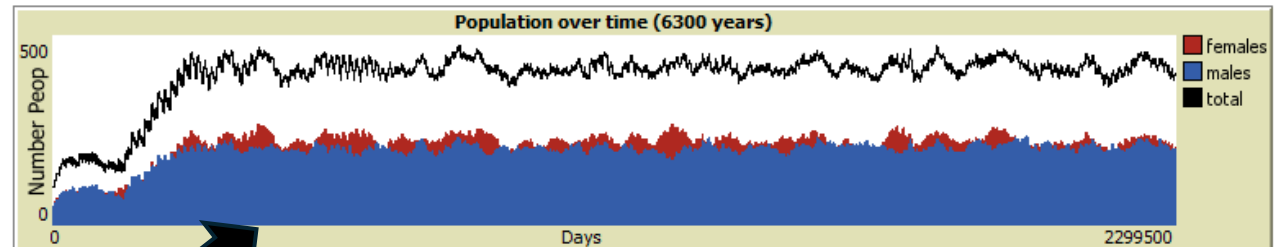
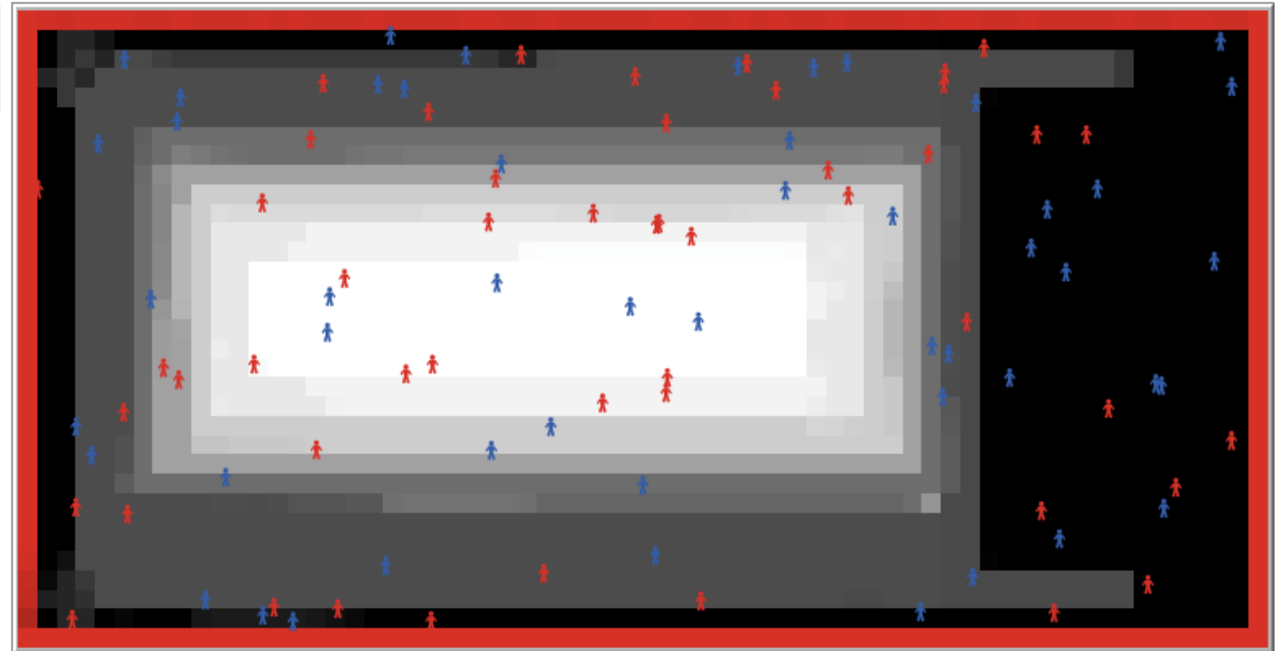
# deaths 30124

# pregnancies 1

# births	# females	# males
30420	15353	15067

After the mission ended, the reason why this was the case is given here:

The mission was successful:  
survivors reached the  
distant planet.



Society fluctuates for the first few centuries, but stabilizes over time



# Extended Model: with Polarizing View logic

Representative for  
opposing views:

religious,  
political,  
ethical,  
national,  
moral,  
etc.

NEW: Killing possible based on polarizing view differences

- Each agent: born with random pv value between 0-10
- if two agents meet outside the safety-zone (white) on ship
  - check differences of polarizing view
  - if values are too far from each other: one of the two agents can get killed

Example: Agent A has pv value of 2

Depending on threshold of pv difference:

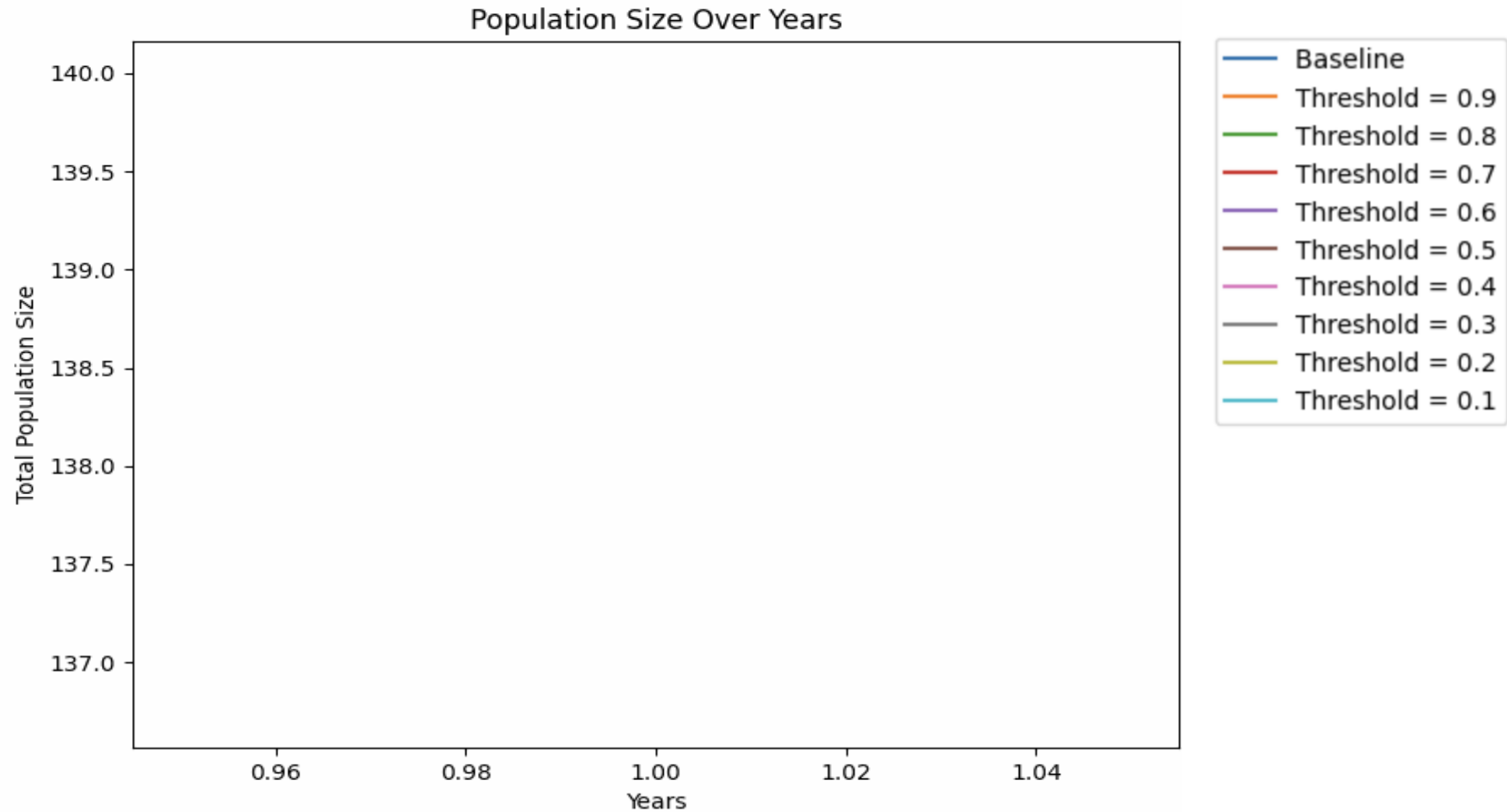
- A and B will try to kill each other if the difference is too big



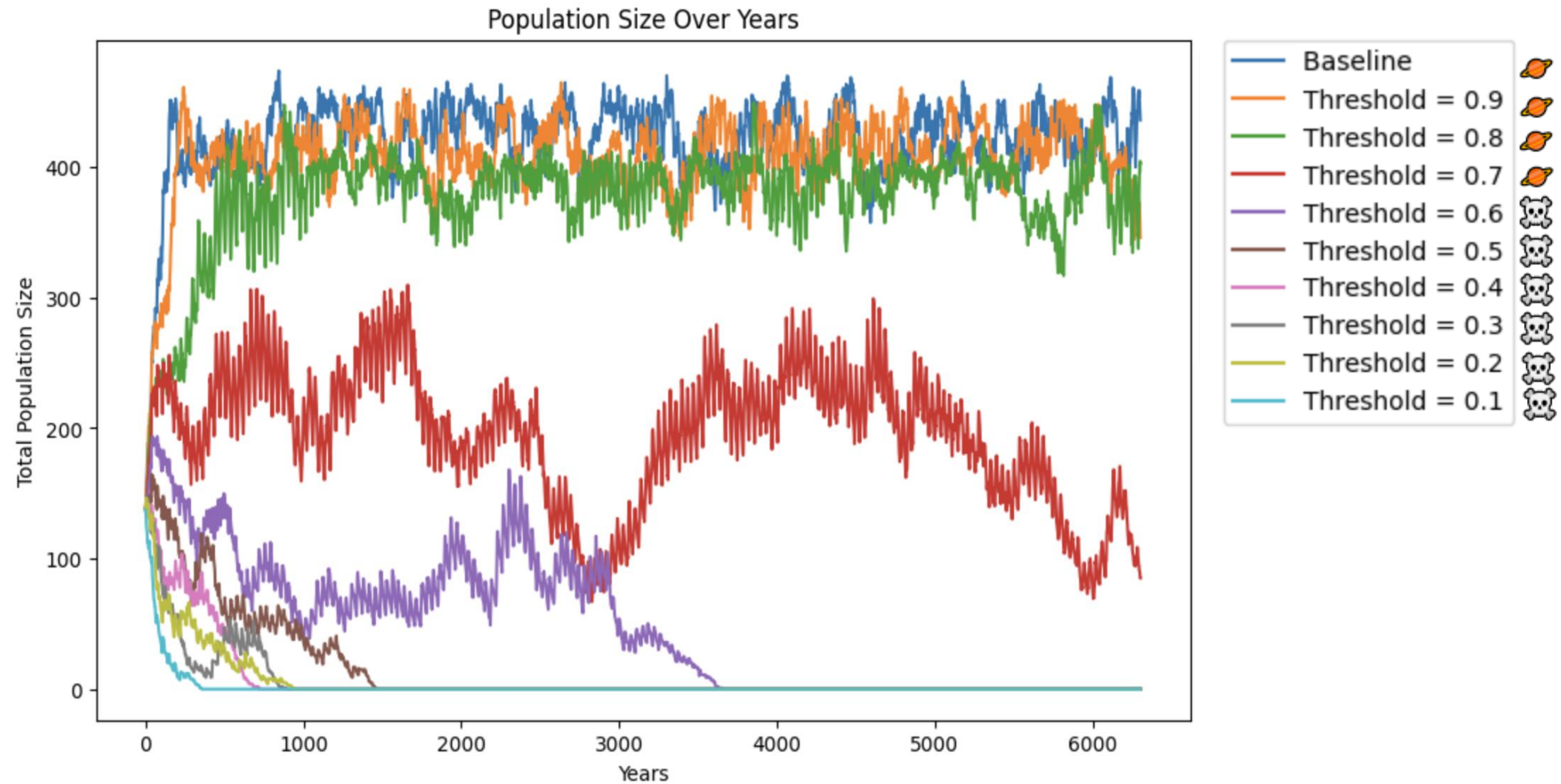
We want to test  
these diff\_thresholds in  
the remaining slides!



# Simulating Populations with Different Thresholds



# Simulating Populations with Different Thresholds



# Analysis 3

Extended Model: includes selectiveness & homicide caused by polarizing views (at view\_difference > 7)

## Initial parameters:

initialCrewSize 100 people

☐ On simulateMonthsInsteadOfDays

### Crew's initial age:

initialAgeFemales 20 years

initialAgeMales 20 years

initialAgeStdDeviation 22 years

### Max. age:

maxAgeFemales 85.0 years

maxAgeMales 79.0 years

ageStdDeviation 15 years

### Crew's bio parameters:

infertilityFemales 10 %

infertilityMales 15 %

maxChildrenPerFemale 2.0 children

maxChildrenStdDeviation 0.5

startAgePermittedMating 35 years

endAgePermittedMating 40 years

☐ On useDynamicPermittedMating

### Females's bio parameters:

meanAgeMenopause 48.81 years

ageMenopauseStdDeviation 3.9 years

setup

go

Current Year  
6300

### Males' statistics:

# males
53
# males (infertile)
11
mean age males
47.97

### Females' statistics:

# females
65
# females (infertile)
9
mean age females
47.3

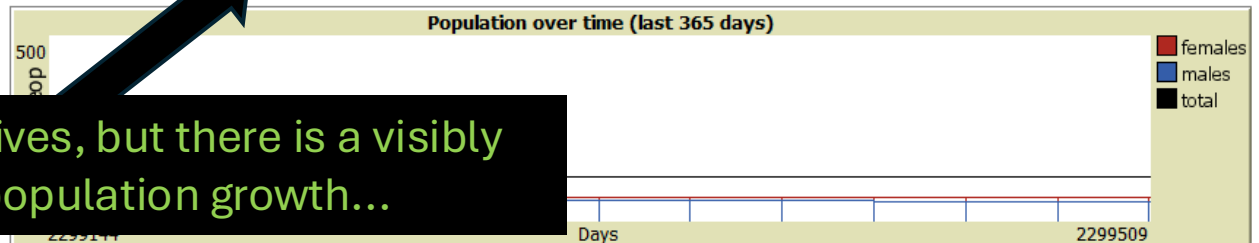
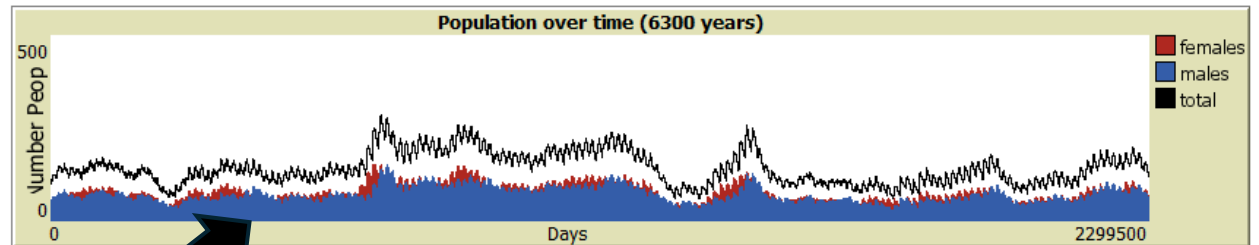
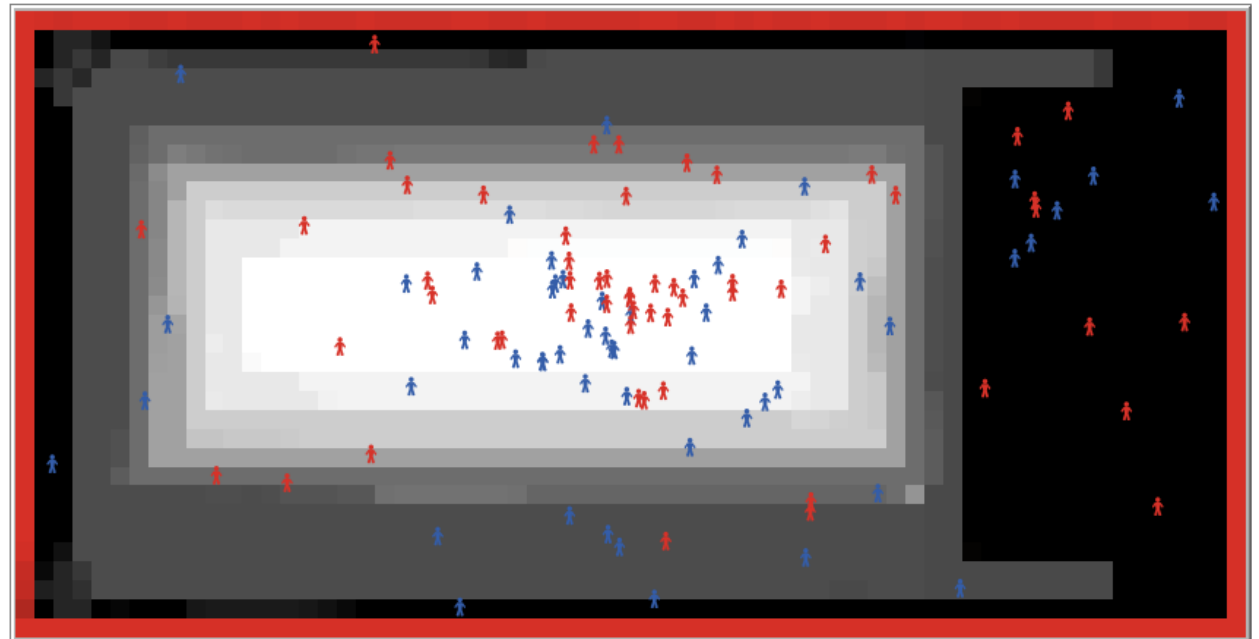
### Crew's statistics:

mean age crew
47.63
# accidents
727
# deaths caused by accidents
125
# deaths
10344
# pregnancies
2
# births
12173
# females
6205
# males
5968

After the mission ended, the reason why this was the case is given here:

The mission was successful: survivors reached the distant planet.

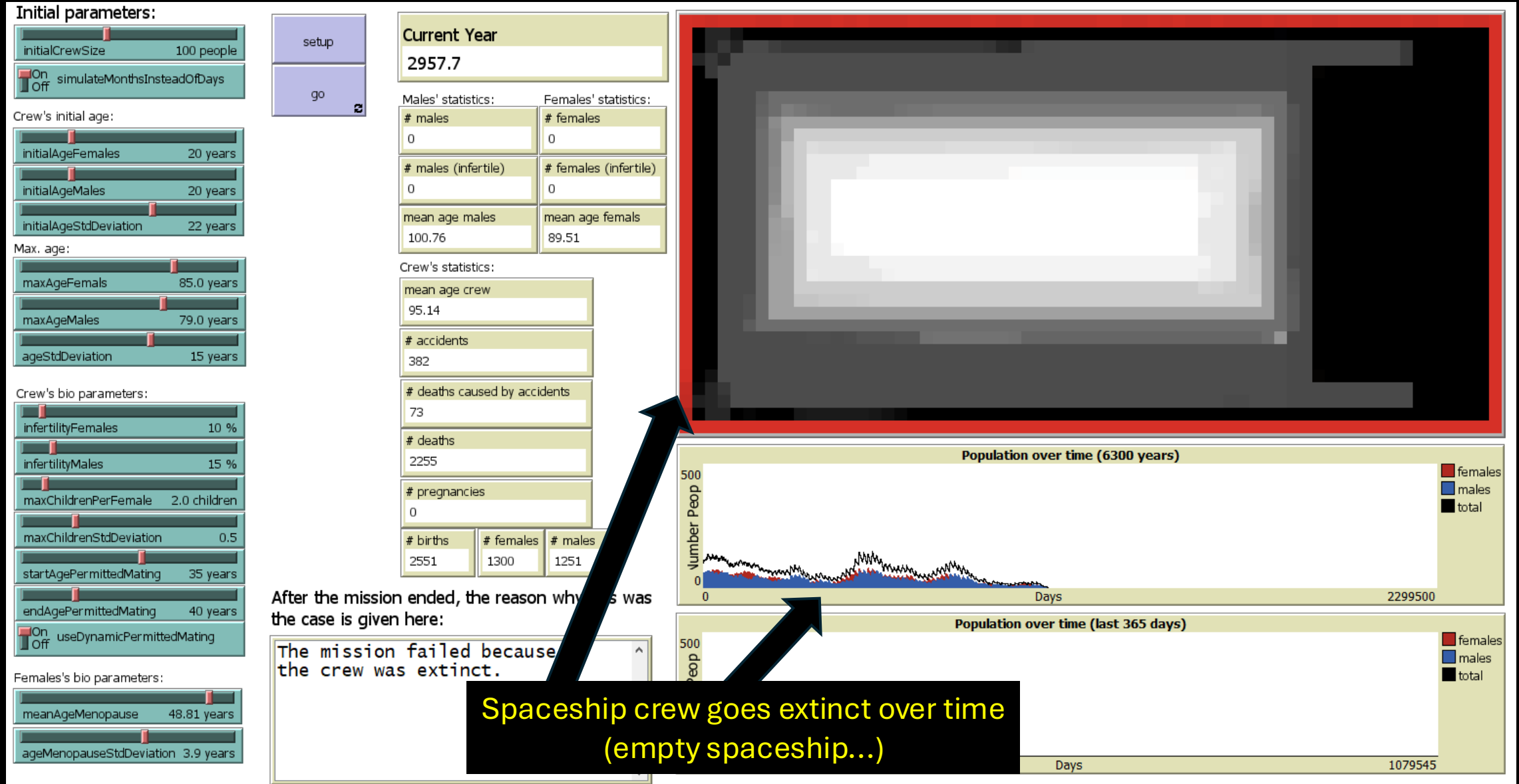
Society survives, but there is a visibly lower population growth...





# Analysis 4

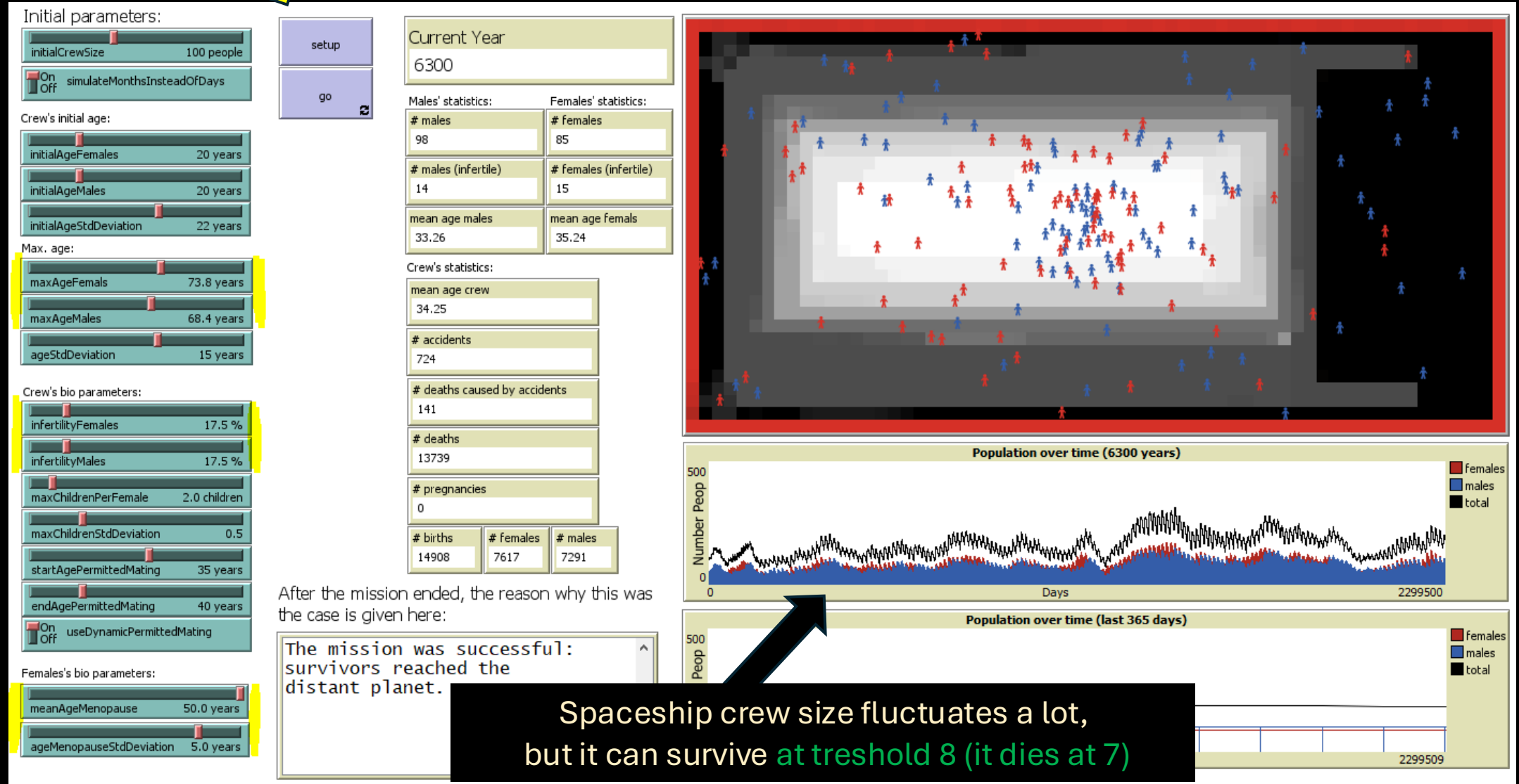
Extended Model: includes selectiveness & homicide caused by polarizing views (at view\_difference > 6)



# Analysis 5

Extended Model: includes selectiveness & homicide caused by polarizing views

Alternative: with our own parameters (based on background research)



# Conclusion



After the introduction of *selective dating preferences*, at what *difference threshold* in *polarizing view values* does the society go extinct because it cannot sustain itself any longer?



- *Selective mating preferences* have an influence on the crew size over time

- *Extended model* incl. *attractiveness* and *polarizing view*:

- Tested with default parameters:

- view\_difference* extinction threshold is between 6 and 7

- Tested with our own parameters: (more tolerant!)

- view\_difference* extinction threshold is between 7 and 8

0 1 2 3 4 5 6 7 8 9 10

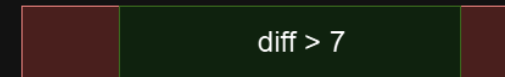


A



B

0 1 2 3 4 5 6 7 8 9 10



A



B

# Limitations & Future Research

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- Computational intensity restricts options
- Trying different distributions
  - of attractiveness
  - of polarizing view
- Different model for mating preferences
  - e.g. maximizing attractiveness
- Examining the unique impact of individual variables
- ABM modelling of a society is a complex process





# Thank you for your attention!

# Group 17

## References

- [1] Github: Simulation of a 6,300-year intergalactic journey  
<https://github.com/SommerEngineering/Simulation-of-long-distance-space-flight?tab=readme-ov-file>
- [2] Sommer, Thorsten (2019). Simulation of a long-distance space flight. DOI: 10.5281/zenodo.3382912
- [3] Sommer, Thorsten (2019). Simulation of a 6,300-year intergalactic journey. DOI: 10.17504/protocols.io.676hhre
- [4] Experiment of Frédéric Marin and Camille Beluffi from 2018: <https://arxiv.org/abs/1806.03856>
- [5] Sircova A, Karimi F, Osin EN, Lee S, Holme P, et al. (2015) Simulating Irrational Human Behavior to Prevent Resource Depletion. PLOS ONE 10(3): e0117612.  
<https://doi.org/10.1371/journal.pone.0117612>
- [6] Kalick, S. M., & Hamilton, T. E. (1986). The matching hypothesis reexamined. *Journal of Personality and Social Psychology*, 51(4), 673–682. <https://doi.org/10.1037/0022-3514.51.4.673>
- [7] Szocik, K. (2019). Should and could humans go to Mars? Yes, but not now and not in the near future. *Futures*, 105, 54–66. <https://doi.org/10.1016/j.futures.2018.08.004>
- [8] Salotti, J.-M. (2020). Minimum Number of Settlers for Survival on Another Planet. *Scientific Reports*, 10(1), 9700. <https://doi.org/10.1038/s41598-020-66740-0>
- [9] Haqq-Misra, J., Wolf, E. T., Welsh, W. F., Kopparapu, R. K., Kostov, V., & Kane, S. R. (2019). Constraining the Magnitude of Climate Extremes From Time-Varying Insolation on a Circumbinary Terrestrial Planet. *Journal of Geophysical Research: Planets*, 124(12), 3231–3243. <https://doi.org/10.1029/2019JE006222>
- [10] Marin, F., & Beluffi, C. (2018). *Computing the minimal crew for a multi-generational space travel towards Proxima Centauri b* (Version 1). arXiv. <https://doi.org/10.48550/ARXIV.1806.03856>
- [11] Haqq-Misra, J. (2019). Can Deep Altruism Sustain Space Settlement? In K. Szocik (Ed.), *The Human Factor in a Mission to Mars* (pp. 145–155). Springer International Publishing.  
[https://doi.org/10.1007/978-3-030-02059-0\\_8](https://doi.org/10.1007/978-3-030-02059-0_8)