Group 17

Agent-based Modelling (ABM)

Simulating Societal Collapse in Multi-Generational Space Travel

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Existing Literature

… 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)

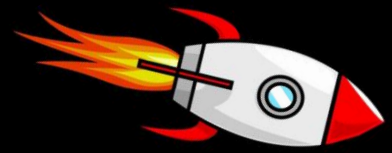
Motivation

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

Take Examples from Lecture:

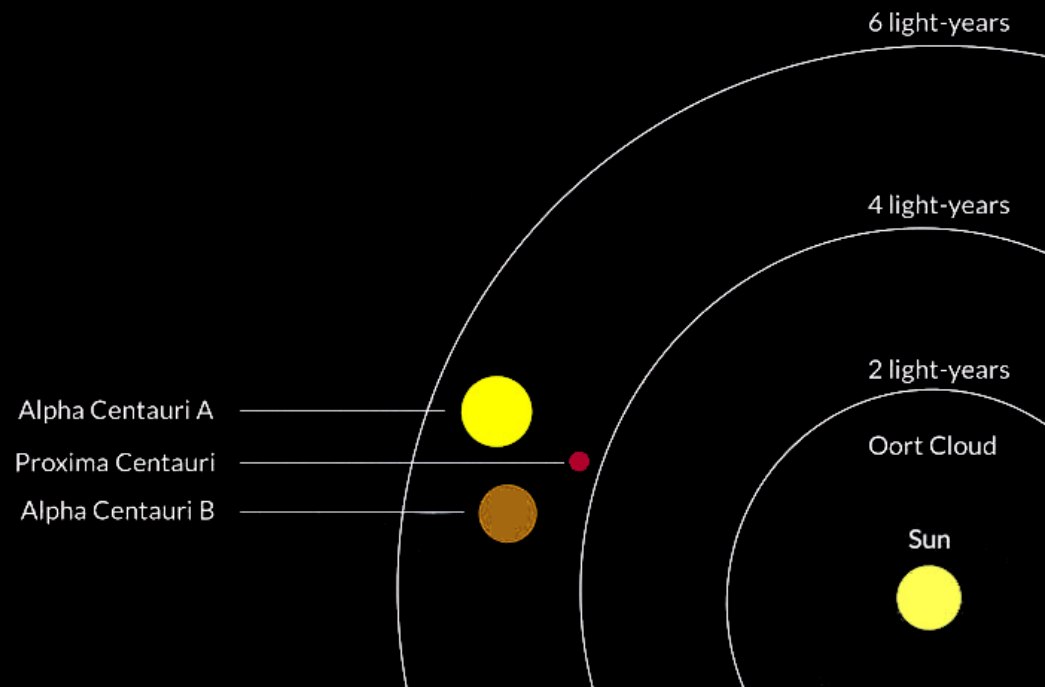
- *Dating Choice Model* by Kalick and Hamilton (1986)
- *Simulating Irrational Human Behavior to Prevent Resource Depletion* by Sircova, Karimi, Osin, Holme, Strömbom (2015)
- Granovetter Threshold Model (1978)
- Opinion Dynamics

Base Model



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

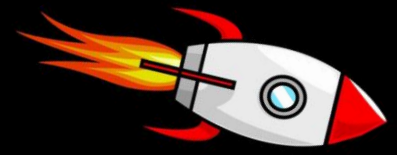
- Model initially based on an astrophysics paper [1]
- ABM approach based on Netlogo model [2]
  - Simulation of long-distance space flight
  - contains realistic data
  - parameters set based on research



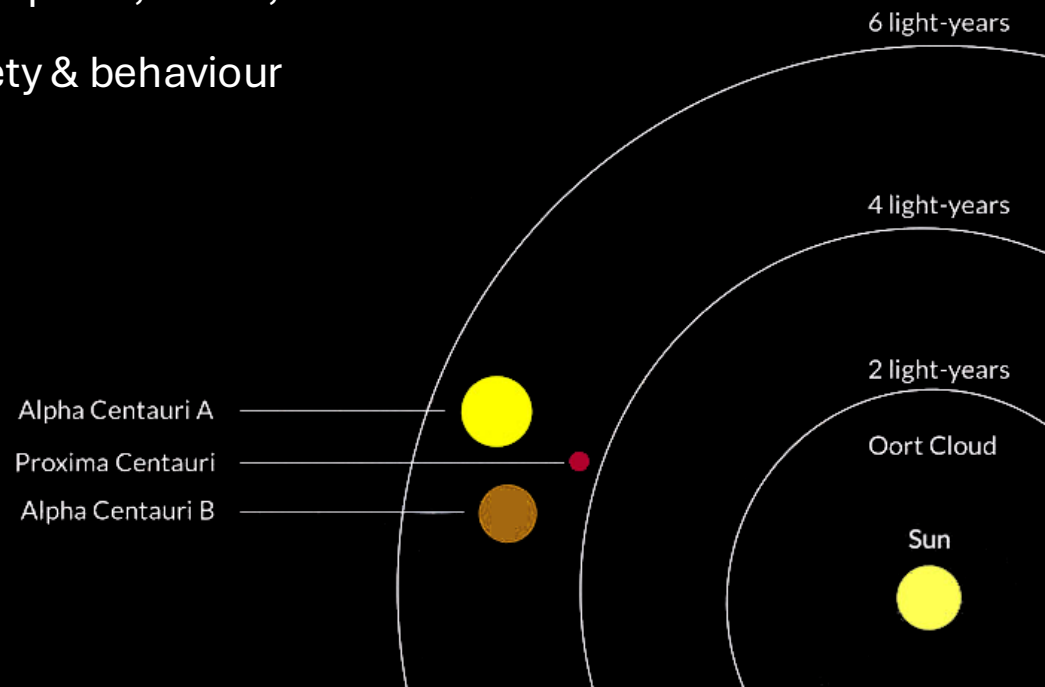
[1] *"Computing the minimal crew for a multi-generational space travel towards Proxima Centauri b"* by Marin & Beluffi (2018)

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

Base Model

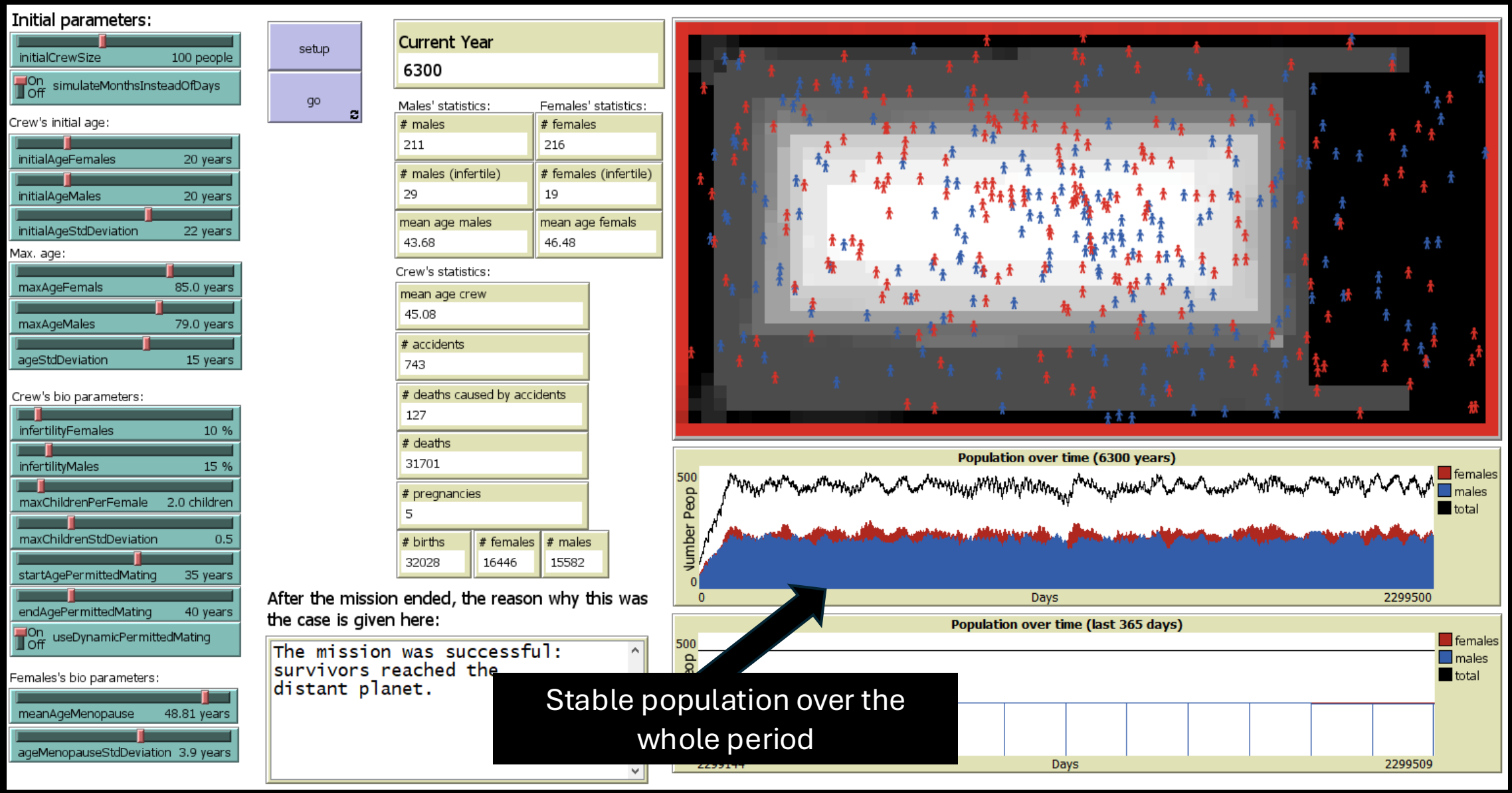


- Base Model simulates life on spaceship
- Agents: male & female, movement, mating, pregnancy
- Parameters: crew size, fertility, age, mating behaviour
- Observation mechanics: population over time, accidents, crew demographics, births, deaths
- Assumptions: infinite resources, no maintenance needed, 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)



Extended Model: with Selectiveness logic

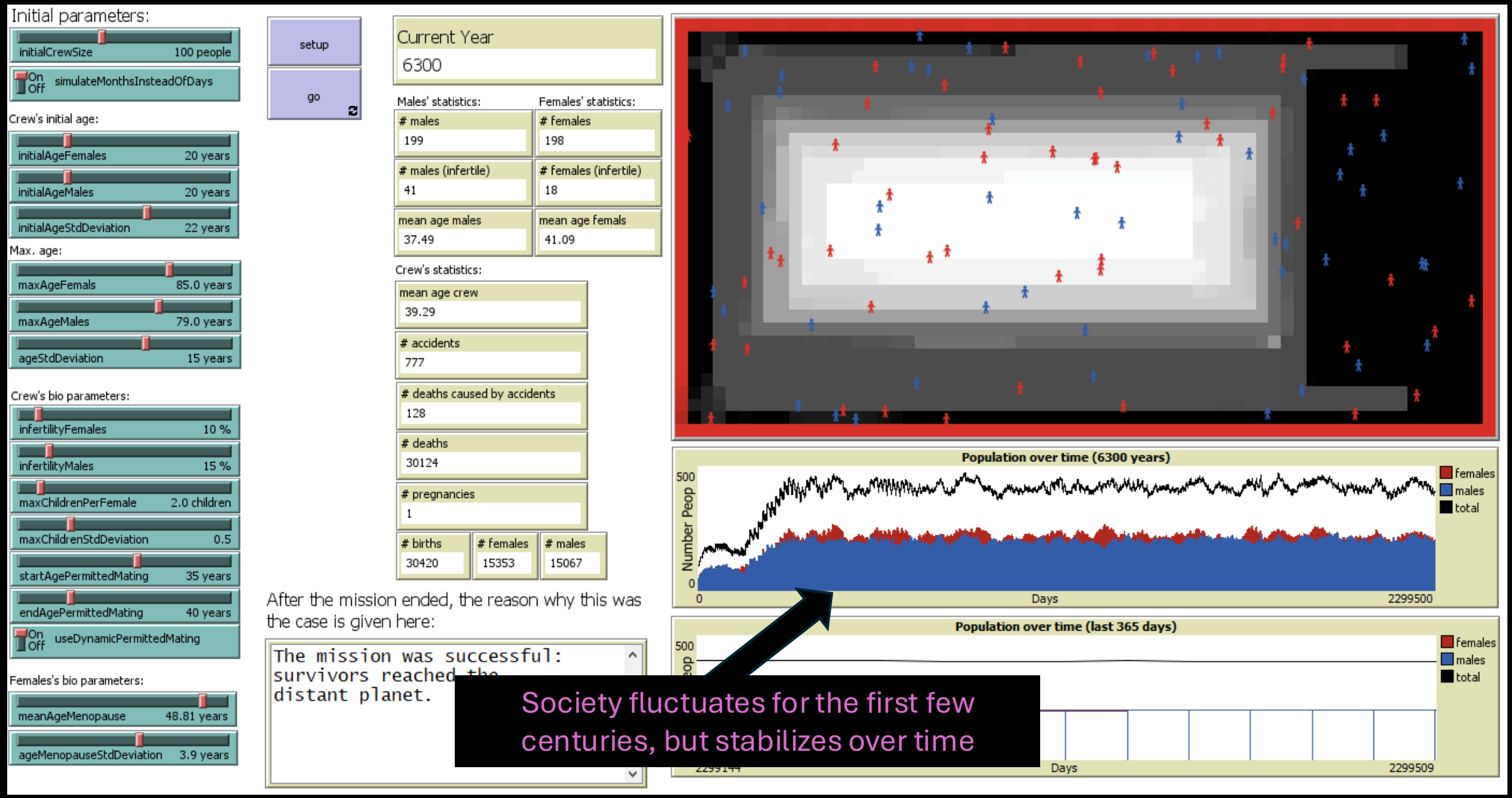
- NEW: Determine the probability of mating
- Process simulates a more realistic social interaction
- Attractiveness-based mate selection simulates mutual consent
- Attractiveness value assigned randomly
  - at birth of each agent (random 0-10)
- When two agents meet:
  - calculate individual differences 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 treshold 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



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

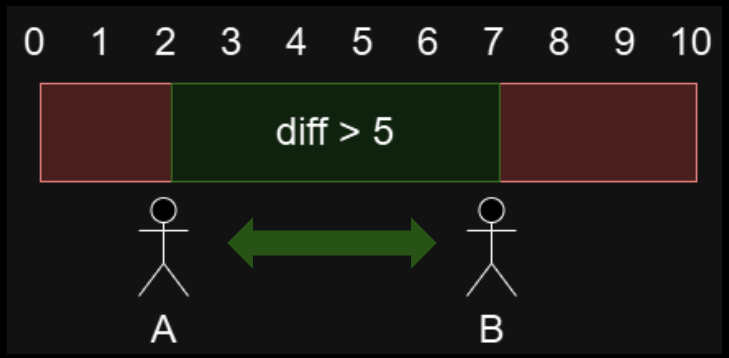
- Each agent: born with random pv value between 0-10
- if two agents meet outside the safety-zone (white) on ship
  - check differences of polarizing view
  - if values are too far from each other: one of the two agents can get killed

Example: Agent A has pv value of 2

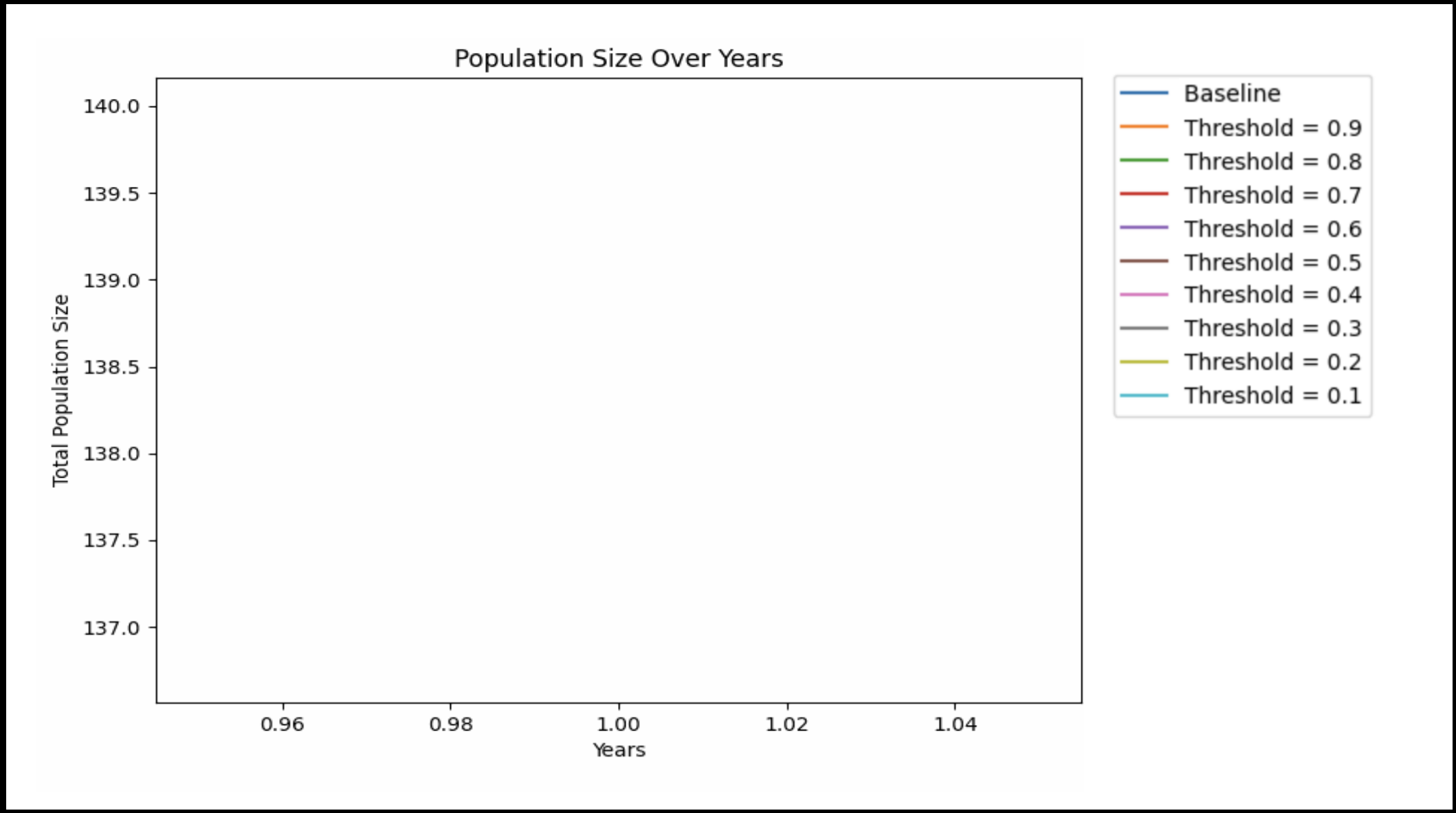
Depending on treshold of pv difference:

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

We want to test these diff_tresholds in the remaining slides!



Simulating Populations with Different Thresholds



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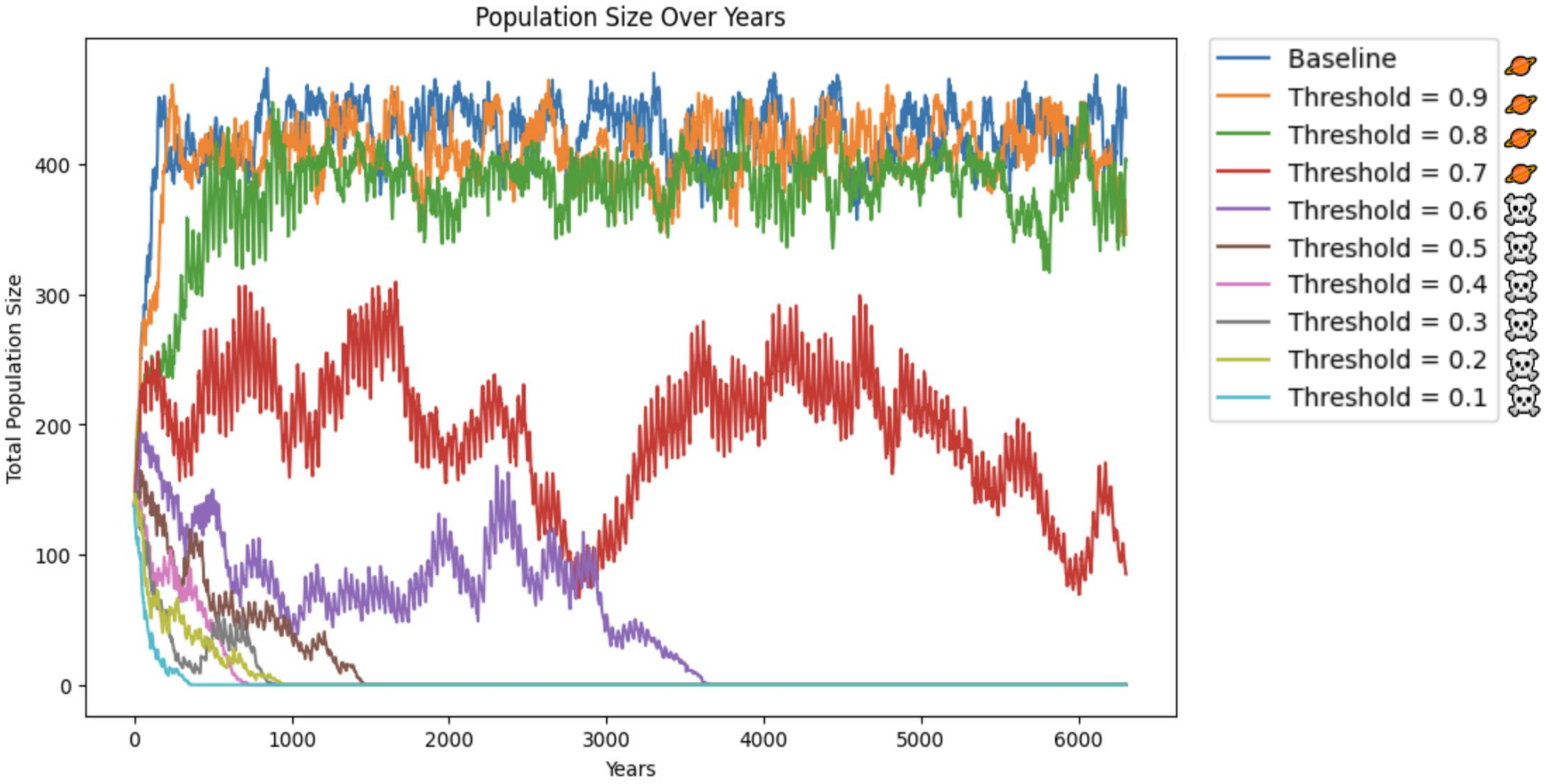
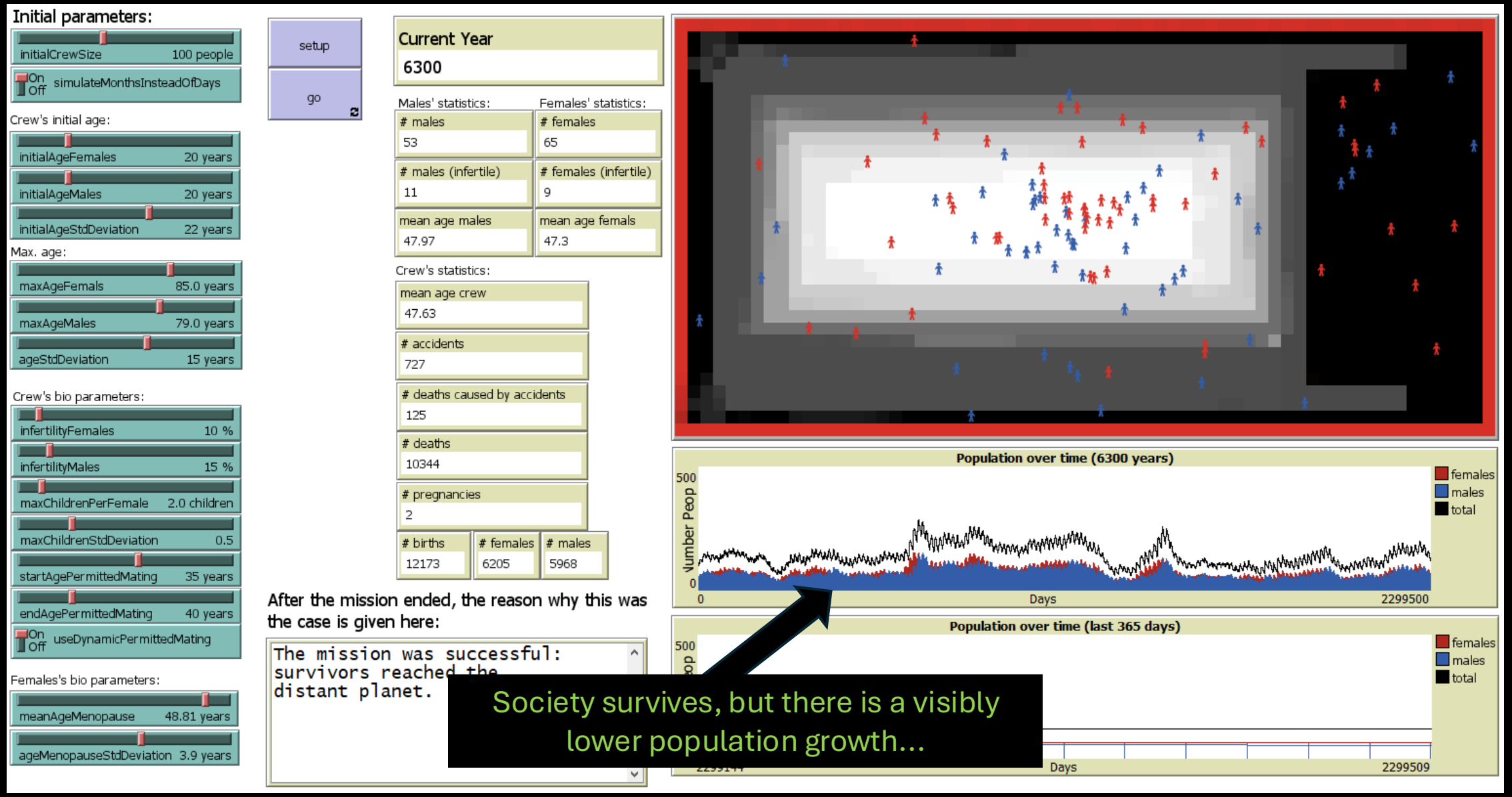


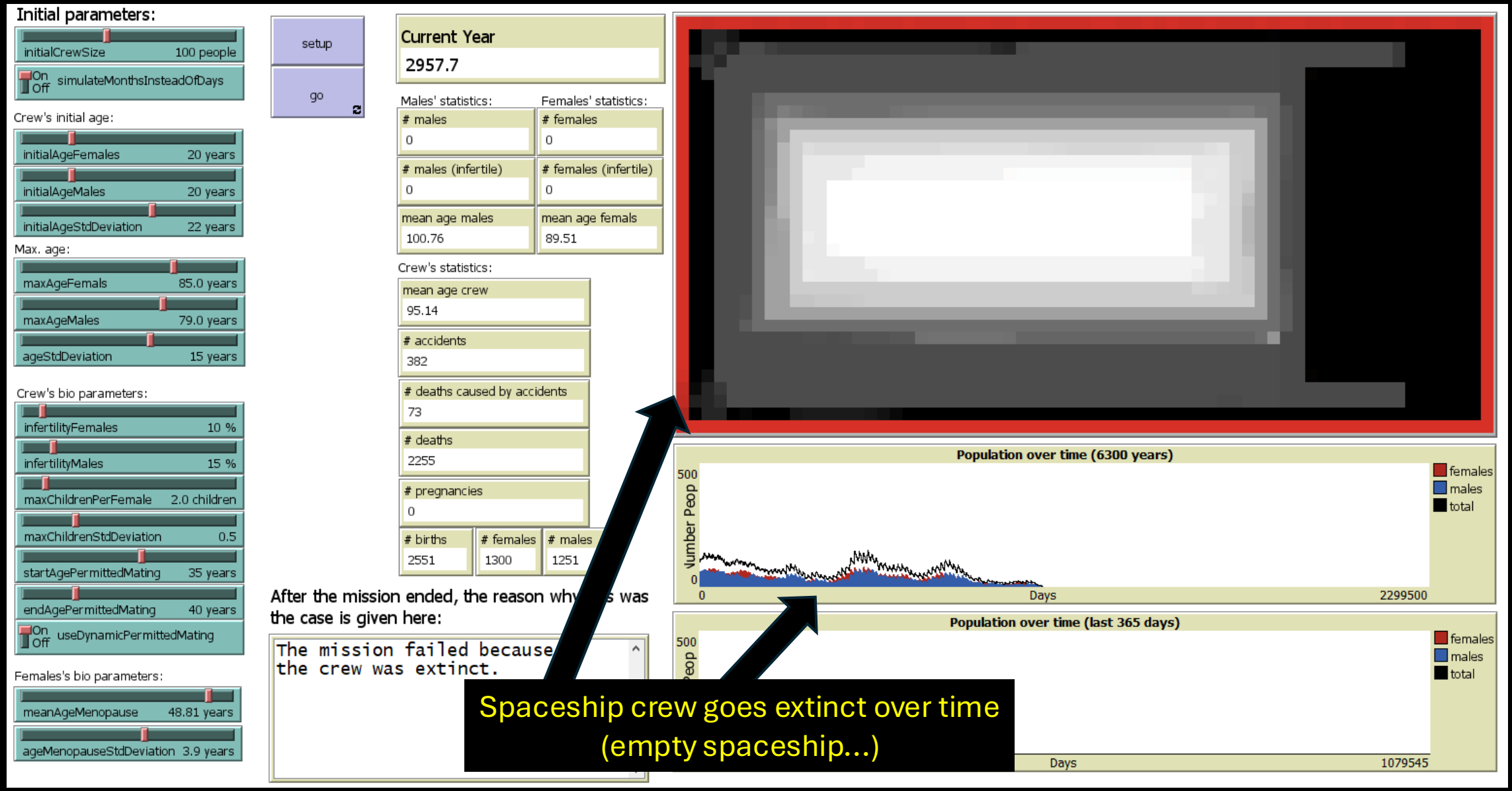
Analysis 3

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



Analysis 4

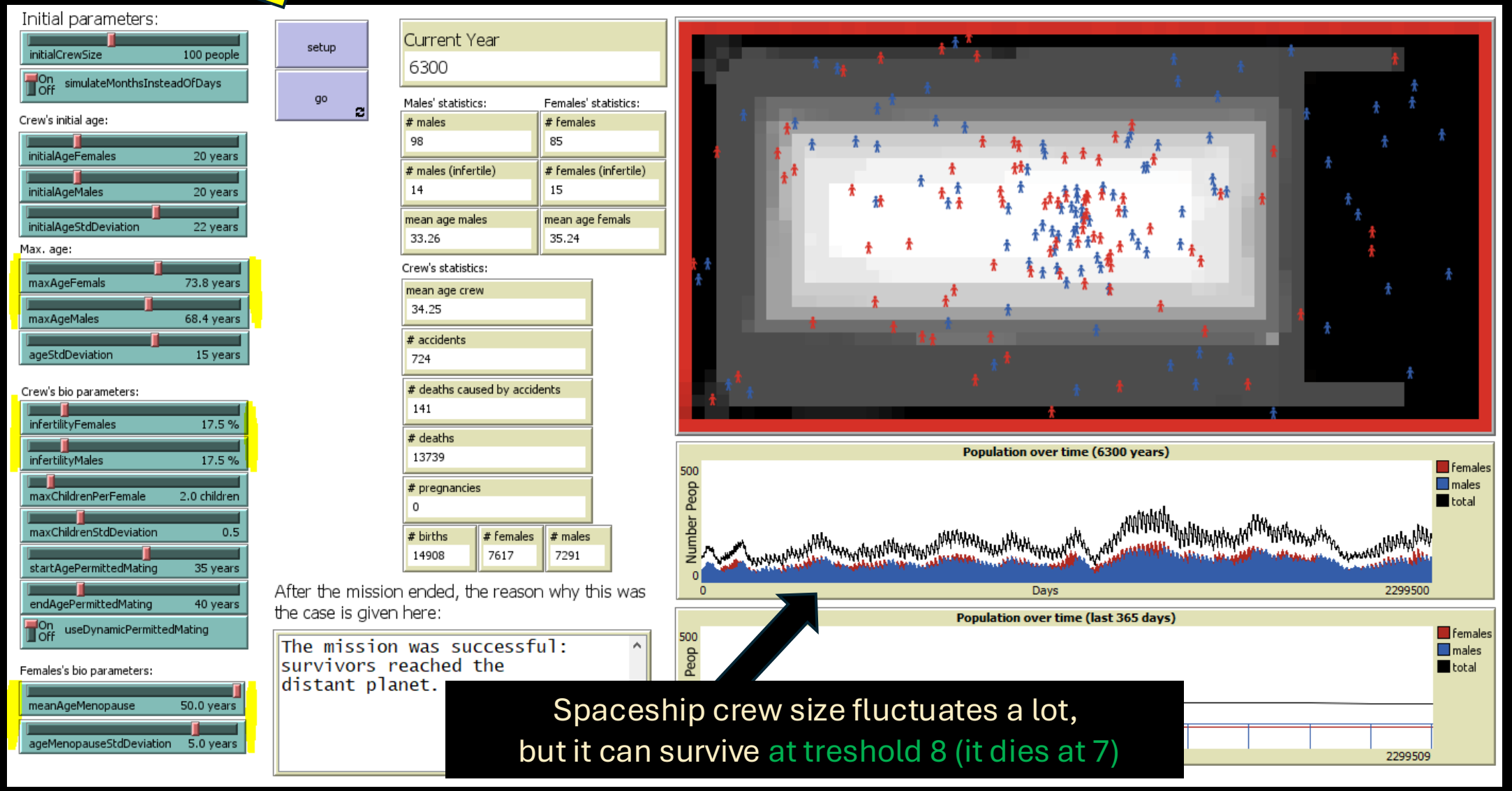
Extended Model: includes selectiveness &
homicide caused by polarizing views (at view_difference > 6)



Analysis 5

Extended Model: includes selectiveness & homicide caused by polarizing views

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



Spaceship crew size fluctuates a lot,
but it can survive at treshold 8 (it dies at 7)

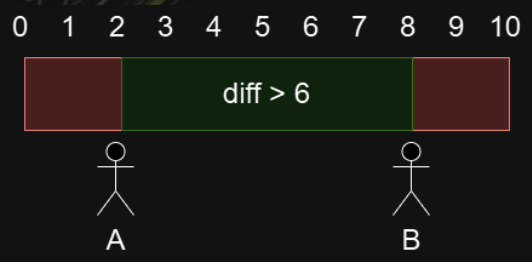
Conclusion

After the introduction of selective dating preferences, at what difference treshold 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: (more tolerant!)

    view_difference extinction treshold is between 6 and 7
  - Tested with our own parameters:

    view_difference extinction treshold is between 7 and 8



Limitations & Future Research

- Computational intensity restricts options
- Trying different distributions
  - of attractiveness
  - of polarizing view
- Different model for mating preferences
  - e.g. maximizing attractivity
- 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

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[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 Instellation on a Circumbinary Terrestrial Planet. *Journal of Geophysical Research: Planets*, *124*(12), 3231–3243. https://doi.org/10.1029/2019JE006222

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