Appendix: Simulation Model Code

Hierarchy in Mixed Relation Networks:
Warfare Advantage and Resource Distribution in Simulated World-Systems

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Notes from the authors:

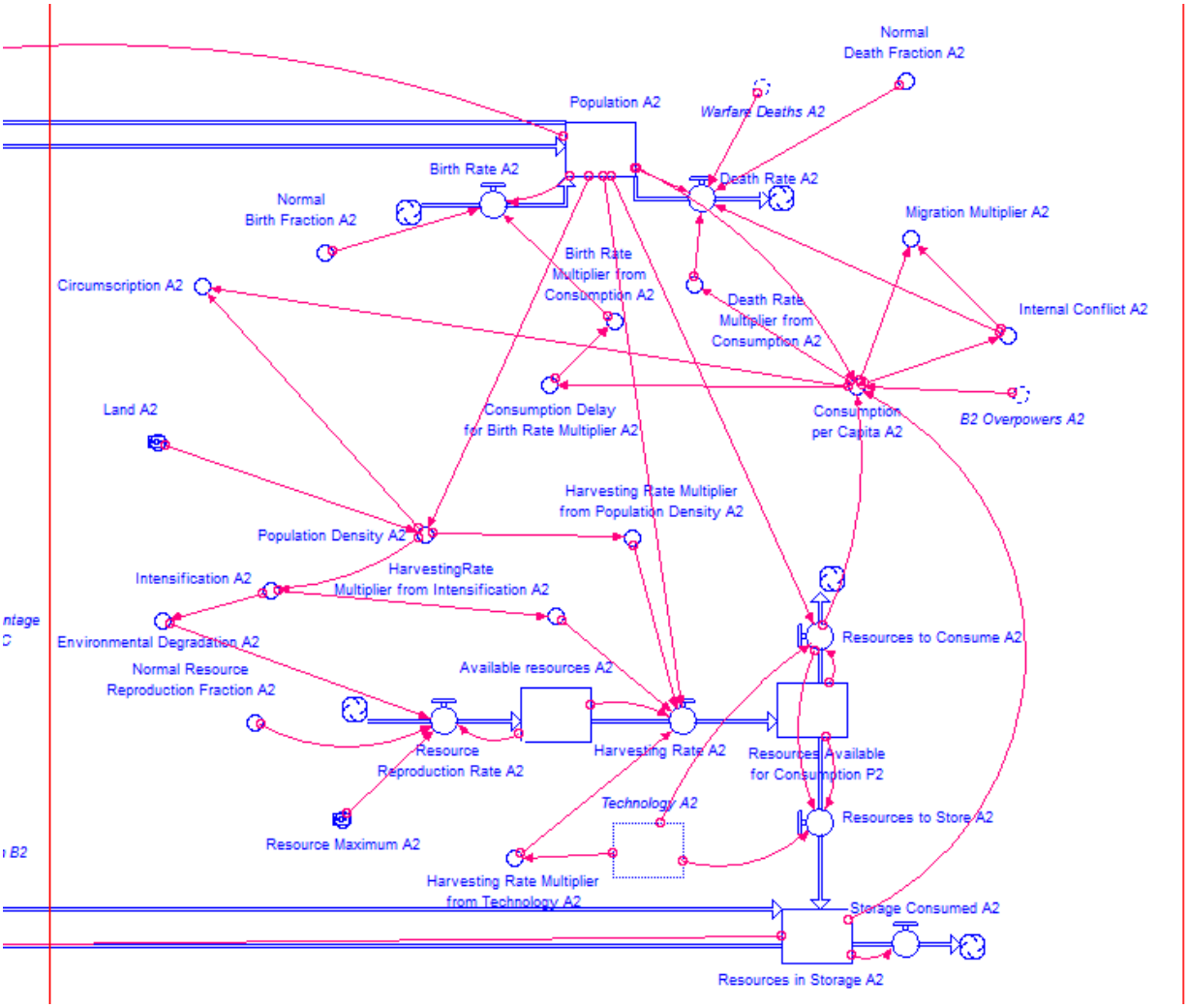
The equations below were used by the software program STELLA to generate the simulation model.

All of the code has been copied directly from the software program and is unaltered except for the following changes: Any notes in brackets [] are not in the code and added by the authors for the purpose of clarification. Bolding or italicizing of sectors and variables as well as horizontal line breaks have been added to improve readability.

Variables followed by the "(Not in a sector)" comment are defined near the end of the document. This is how STELLA chooses to report them because they are not contained within a single society or "sector".

All variable definitions have been separated by an empty line. Variables that STELLA treats as "stocks" have been bolded. These are variables used to represent anything that accumulates. "Flow" variables (inflows and outflows) are contained in the subsections for each stock that they flow to or from. They represent processes that lead to inputs and outputs to stocks and change the magnitude of stocks in the system. "Converter" variables have been italicized. These variables store constants as well as take in and transform information used by other variables in the model.

View in STELLA of a single society (A2):



SOCIETY A1

Available_resources_A1(t) = Available_resources_A1(t - dt) + (Resource__Reproduction_Rate_A1 - Harvesting_Rate_A1) * dtINIT

Available_resources_A1 = 200 [for t = 0]

INFLOWS:
Resource__Reproduction_Rate_A1 = (Environmental_Degradation_A1)*(Normal_Resource_Reproduction_Fraction_A1*200*(1-(Available_resources_A1/Resource_Maximum_A1)))

[The resource re-grows in a linear fashion at low values and approaches an asymptote at the value of Resource_Maximum_A1. This functional form was suggested in the following source: Turchin, Peter. 2003. *Complex Population Dynamics*. Princeton, NJ: Princeton University Press.]

OUTFLOWS:
Harvesting_Rate_A1 = MIN(Population_A1*HarvestingRate__Multiplier_from_Intensification_A1*Harvesting_Rate_Multiplier_from_Population_Density_A1 * Harvesting_Rate_Multiplier_from_Technology_A1, Available_resources_A1)

Resources_Available__for_Consumption_A1(t) = Resources_Available__for_Consumption_A1(t - dt) + (Harvesting_Rate_A1 - Resources_to_Store_A1 - Resources_to_Consume_A1) * dtINIT

Resources_Available__for_Consumption_A1 = 100 [for t = 0]

INFLOWS:
Harvesting_Rate_A1 = MIN(Population_A1*HarvestingRate__Multiplier_from_Intensification_A1*Harvesting_Rate_Multiplier_from_Population_Density_A1 * Harvesting_Rate_Multiplier_from_Technology_A1, Available_resources_A1)

OUTFLOWS:
Resources_to_Store_A1 = IF
Technology_A1 < 1
THEN
0
ELSE
Resources_Available__for_Consumption_A1-Resources_to_Consume_A1

Resources_to_Consume_A1 = IF
Technology_A1 < 1
THEN
MIN(Resources_Available__for_Consumption_A1, 2*Population_A1)
ELSE
MIN(Population_A1,Resources_Available__for_Consumption_A1)

Resources_in_Storage_A1(t) = Resources_in_Storage_A1(t - dt) + (Resources_to_Store_A1 + B1_Trades_to_A1 - A1_Trades_to_B1 - Storage_Consumed_A1) * dtINIT

Resources_in_Storage_A1 = 0 [for t = 0]

INFLOWS:
Resources_to_Store_A1 = IF
Technology_A1 < 1
THEN
0
ELSE
Resources_Available__for_Consumption_A1-Resources_to_Consume_A1

B1_Trades_to_A1 (Not in a sector)

OUTFLOWS:
A1_Trades_to_B1 (Not in a sector)

Storage_Consumed_A1 = Resources_in_Storage_A1

Population_A1(t) = Population_A1(t - dt) + (Birth_Rate_A1 + B1_Migrates_to_A1 - Death_Rate_A1 - A1_Migrates_to_B1) * dtINIT

Population_A1 = 100 [for t = 0]

INFLOWS:
Birth_Rate_A1 =
DELAY(ROUND(Normal_Birth_Fraction_A1*Population_A1*Birth_Rate_Multiplier_from_Consumption_A1),0.75)

[Each iteration is treated as a single year in our model so the birth rate is determined by conditions 9 months prior which is a delay of 0.75 iterations.]

B1_Migrates_to_A1 (Not in a sector)

OUTFLOWS:
Death_Rate_A1 =
ROUND((Population_A1*Normal_Death_Fraction_A1*Death_Rate_Multiplier_from_Consumption_A1) * (1+Internal_Conflict_A1)+ Warfare_Deaths_A1)

A1_Migrates_to_B1 (Not in a sector)

Birth_Rate_Multiplier_from_Consumption_A1 = IF
Consumption_Delay_for_Birth_Rate_Multiplier_A1 < 1
THEN
Consumption_Delay_for_Birth_Rate_Multiplier_A1
ELSE

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2.5*Consumption_Delay_for_Birth_Rate_Multiplier_A1-1.5

[The birth rate multipliers from consumption are piecewise linear functions
of delayed consumption levels that ramp up when the ratios of resources to
humans grow above subsistence levels.]

Circumscription_A1 = IF
Consumption__per_Capita_A1 >= 1
THEN
0.1024*exp((7.67*Population_Density_A1)-7.93)
ELSE
0.1024*exp((7.67*Population_Density_A1)-(7.93*Consumption__per_Capita_A1))

[Circumscription is an exponential function of population density that grows
from 0 to 1 while population density grows from 0 to 1.5. When pop density is
less than 1, circumscription is also dependent on consumption per capita and
grows faster for lower values of consumption per capita.]

Consumption_Delay_for_Birth_Rate_Multiplier_A1 =
DELAY(Consumption__per_Capita_A1,0.75)

Consumption__per_Capita_A1 = IF
Population_A1 >0
THEN
IF
B1_Overpowers_A1 = 0
THEN
MIN(((Resources_to_Consume_A1+Resources_in_Storage_A1)/Population_A1), 2)
ELSE
MIN((Resources_to_Consume_A1)/Population_A1, 0.995)
ELSE
0

Death_Rate_Multiplier_from_Consumption_A1 = IF Consumption__per_Capita_A1 < 1
THEN
-9*Consumption__per_Capita_A1+10
ELSE
IF Consumption__per_Capita_A1 < 2
THEN
-0.2*Consumption__per_Capita_A1+1.2
ELSE
0.8

Environmental_Degradation_A1 = -0.5*DELAY(Intensification_A1, 1)+1.5

HarvestingRate__Multiplier_from_Intensification_A1 = MAX(1.05,
(0.85+0.2*Intensification_A1))
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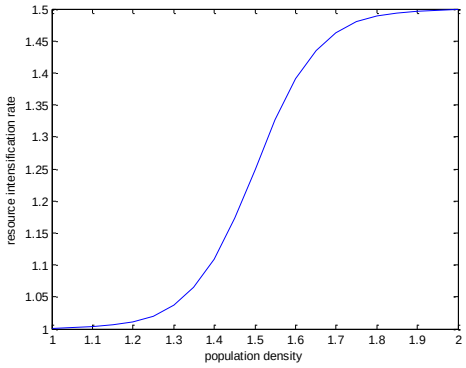
Harvesting_Rate_Multiplier_from_Population_Density_A1 = IF
(Population_Density_A1 < 1)
THEN
1
ELSE (-0.5*Population_Density_A1+1.5)

Harvesting_Rate_Multiplier_from_Technology_A1 = IF
Technology_A1 <= 0
THEN
1
ELSE
(1/(1+89*EXP(-1.8*Technology_A1)))+1

[The harvesting rate multiplier is a logistic function of technology ranging from approximately 1 to 2 as technology grows from 0 to ∞.]

Intensification_A1 = IF
Population_Density_A1 <= 1
THEN
1
ELSE
(1/(2*(1+12000000*EXP(-13*Population_Density_A1))))+1

[The intensification efforts defined as "the investment of more soil, water, minerals, or energy per unit time or area" by Marvin Harris (1977. *Cannibals and Kings: The Origins of Cultures*. New York: Random House.) is a logistic function of population density. It ranges from 1 to 1.5 as population density grows between 1 and 2 (pop density < 1 leads to intensification of 1; pop density > 2 leads to intensification of 1.5).

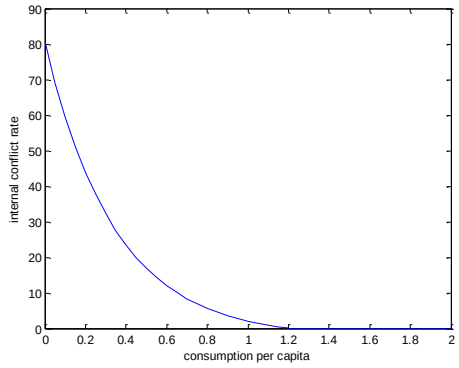


]

Internal_Conflict_A1 = IF Consumption__per_Capita_A1 < 1
THEN
-0.95*Consumption__per_Capita_A1+1
ELSE
IF Consumption__per_Capita_A1 < 2
THEN
-0.05*Consumption__per_Capita_A1+0.1
ELSE

0

[Internal conflict is a negative exponential function of consumption per capita that hits 0 at the consumption per capita value of 1.2.



]

Land_A1 = 100

Migration_Multiplier_A1 =
IF (Consumption__per_Capita_A1 < 0.8)
THEN
((-0.5*Consumption__per_Capita_A1+0.5) + 0.5*Internal_Conflict_A1)
ELSE IF (Consumption__per_Capita_A1 > 1.2)
THEN 0.5*Internal_Conflict_A1
ELSE ((-0.25*Consumption__per_Capita_A1+0.3) + 0.5*Internal_Conflict_A1)

[The migration multiplier can be viewed as simply the addition of two separate multipliers; one from consumption per capita and the other from internal conflict. The multiplier from internal conflict is always equivalent to half the internal conflict value. The multiplier from consumption per capita is a piecewise linear function of consumption.]

Normal_Birth_Fraction_A1 = NORMAL(0.04, 0.01)

Normal_Death_Fraction_A1 = NORMAL(0.02, 0.005)

Normal_Resource_Reproduction_Fraction_A1 = NORMAL(1.2, 0.05)

Population_Density_A1 = Population_A1/Land_A1

Resource_Maximum_A1 = 400

SOCIETY A2

Available_resources_A2(t) = Available_resources_A2(t - dt) + (Resource__Reproduction_Rate_A2 - Harvesting_Rate_A2) * dtINIT

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Available_resources_A2 = 200  [for t = 0]

INFLOWS:
Resource__Reproduction_Rate_A2 =
(Environmental_Degradation_A2)*(Normal_Resource_Reproduction_Fraction_A2*200*
(1-(Available_resources_A2/Resource_Maximum_A2)))

OUTFLOWS:
Harvesting_Rate_A2 =
MIN(Population_A2*HarvestingRate__Multiplier_from_Intensification_A2*Harvesti
ng_Rate_Multiplier_from_Population_Density_A2 *
Harvesting_Rate_Multiplier_from_Technology_A2, Available_resources_A2)

Population_A2(t) = Population_A2(t - dt) + (Birth_Rate_A2 + B2_Migrates_to_A2
- Death_Rate_A2 - A2_Migrates_to_B2) * dtINIT

Population_A2 = 100  [for t = 0]

INFLOWS:
Birth_Rate_A2 =
DELAY(ROUND(Normal_Birth_Fraction_A2*Population_A2*Birth_Rate_Multiplier_from
_Consumption_A2),0.75)

B2_Migrates_to_A2  (Not in a sector)

OUTFLOWS:
Death_Rate_A2 =
ROUND((Population_A2*Normal_Death_Fraction_A2*Death_Rate_Multiplier_from_Cons
umption_A2) * (1+ Internal_Conflict_A2)+ Warfare_Deaths_A2)

A2_Migrates_to_B2  (Not in a sector)

Resources_Available__for_Consumption_A2(t) =
Resources_Available__for_Consumption_A2(t - dt) + (Harvesting_Rate_A2 -
Resources_to_Store_A2 - Resources_to_Consume_A2) * dtINIT

Resources_Available__for_Consumption_A2 = 100  [for t = 0]

INFLOWS:
Harvesting_Rate_A2 =
MIN(Population_A2*HarvestingRate__Multiplier_from_Intensification_A2*Harvesti
ng_Rate_Multiplier_from_Population_Density_A2 *
Harvesting_Rate_Multiplier_from_Technology_A2, Available_resources_A2)

OUTFLOWS:
Resources_to_Store_A2 = IF
Technology_A2 < 1
THEN
0
```

```
ELSE
Resources_Available__for_Consumption_A2-Resources_to_Consume_A2

Resources_to_Consume_A2 = IF
Technology_A2 < 1
THEN
MIN(Resources_Available__for_Consumption_A2, 2*Population_A2)
ELSE
MIN(Population_A2, Resources_Available__for_Consumption_A2)

Resources_in_Storage_A2(t) = Resources_in_Storage_A2(t - dt) +
(Resources_to_Store_A2 + B2_Trades_to_A2 - A2_Trades_to_B2 -
Storage_Consumed_A2) * dtINIT

Resources_in_Storage_A2 = 0  [for t = 0]

INFLOWS:
Resources_to_Store_A2 = IF
Technology_A2 < 1
THEN
0
ELSE
Resources_Available__for_Consumption_A2-Resources_to_Consume_A2

B2_Trades_to_A2  (Not in a sector)

OUTFLOWS:
A2_Trades_to_B2  (Not in a sector)

Storage_Consumed_A2 = Resources_in_Storage_A2

Birth_Rate_Multiplier_from_Consumption_A2 = IF
Consumption_Delay_for_Birth_Rate_Multiplier_A2 < 1
THEN
Consumption_Delay_for_Birth_Rate_Multiplier_A2
ELSE
2.5*Consumption_Delay_for_Birth_Rate_Multiplier_A2-1.5

Circumscription_A2 = IF
Consumption__per_Capita_A2 >= 1
THEN
0.1024*exp((7.67*Population_Density_A2)-7.93)
ELSE
0.1024*exp((7.67*Population_Density_A2)-(7.93*Consumption__per_Capita_A2))

Consumption_Delay_for_Birth_Rate_Multiplier_A2 =
DELAY(Consumption__per_Capita_A2,0.75)

Consumption__per_Capita_A2 = IF
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```
Population_A2 >0
THEN
IF
B2_Overpowers_A2 = 0
THEN
MIN(((Resources_to_Consume_A2+Resources_in_Storage_A2)/Population_A2), 2)
ELSE
MIN((Resources_to_Consume_A2)/Population_A2, .995)
ELSE
0

Death_Rate_Multiplier_from_Consumption_A2 = IF Consumption__per_Capita_A2 < 1
THEN
-9*Consumption__per_Capita_A2+10
ELSE
IF Consumption__per_Capita_A2 < 2
THEN
-0.2*Consumption__per_Capita_A2+1.2
ELSE
0.8

Environmental_Degradation_A2 = -0.5*DELAY(Intensification_A2, 1)+1.5

HarvestingRate__Multiplier_from_Intensification_A2 = MAX(1.05,
(0.85+0.2*Intensification_A2))

Harvesting_Rate_Multiplier_from_Population_Density_A2 = IF
(Population_Density_A2 < 1)
THEN
1
ELSE (-0.5*Population_Density_A2+1.5)

Harvesting_Rate_Multiplier_from_Technology_A2 = IF
Technology_A2 <= 0
THEN
1
ELSE
(1/(1+89*EXP(-1.8*Technology_A2)))+1

Intensification_A2 = IF
Population_Density_A2 <= 1
THEN
1
ELSE
(1/(2*(1+12000000*EXP(-13*Population_Density_A2))))+1

Internal_Conflict_A2 = IF Consumption__per_Capita_A2 < 1
THEN
-0.95*Consumption__per_Capita_A2+1
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ELSE
IF Consumption__per_Capita_A2 < 2
THEN
-0.05*Consumption__per_Capita_A2+0.1
ELSE
0

Land_A2 = 100

Migration_Multiplier_A2 = IF (Consumption__per_Capita_A2 < 0.8)
THEN
((-0.5*Consumption__per_Capita_A2+0.5) + 0.5*Internal_Conflict_A2)
ELSE IF (Consumption__per_Capita_A2 > 1.2)
THEN
0.5*Internal_Conflict_A2
ELSE ((-0.25*Consumption__per_Capita_A2+0.3) + 0.5*Internal_Conflict_A2)

Normal_Birth_Fraction_A2 = NORMAL(0.04, 0.01)

Normal_Death_Fraction_A2 = NORMAL(0.02, 0.005)

Normal_Resource_Reproduction_Fraction_A2 = NORMAL(1.2, 0.05)

Population_Density_A2 = Population_A2/Land_A2

Resource_Maximum_A2 = 400
```

SOCIETY B1

```
Available_resources_B1(t) = Available_resources_B1(t - dt) +
(Resource__Reproduction_Rate_B1 - Harvesting_Rate_B1) * dtINIT

Available_resources_B1 = 200  [for t = 0]

INFLOWS:
Resource__Reproduction_Rate_B1 =
(Environmental_Degradation_B1)*(Resource_Reproduction_Fraction_B1*200*(1-
(Available_resources_B1/Resource_Maximum_B1)))

OUTFLOWS:
Harvesting_Rate_B1 =
MIN(Population_B1*HarvestingRate__Multiplier_from_Intensification_B1*Harvesti
ng_Rate_Multiplier_from_Population_Density_B1 *
Harvesting_Rate_Multiplier_from_Technology_B1, Available_resources_B1)

Resources_Available__for_Consumption_B1(t) =
Resources_Available__for_Consumption_B1(t - dt) + (Harvesting_Rate_B1 -
Resources_to_Store_B1 - Resources_to_Consume_B1) * dtINIT
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Resources_Available__for_Consumption_B1 = 0 [for t = 0]

INFLOWS:
Harvesting_Rate_B1 =
MIN(Population_B1*HarvestingRate__Multiplier_from_Intensification_B1*Harvesti
ng_Rate_Multiplier_from_Population_Density_B1 *
Harvesting_Rate_Multiplier_from_Technology_B1, Available_resources_B1)

OUTFLOWS:
Resources_to_Store_B1 = IF
Technology_B1 < 1
THEN
0
ELSE
Resources_Available__for_Consumption_B1-Resources_to_Consume_B1

Resources_to_Consume_B1 = IF
Technology_B1 < 1
THEN
MIN(Resources_Available__for_Consumption_B1, 2*Population_B1)
ELSE
MIN(Population_B1,Resources_Available__for_Consumption_B1)

Resources_in_Storage_B1(t) = Resources_in_Storage_B1(t - dt) +
(Resources_to_Store_B1 + C_Trades_to_B1 + A1_Trades_to_B1 - B1_Trades_to_C -
Storage_Consumed_B1 - B1_Trades_to_A1) * dtINIT

Resources_in_Storage_B1 = 0 [for t = 0]

INFLOWS:
Resources_to_Store_B1 = IF
Technology_B1 < 1
THEN
0
ELSE
Resources_Available__for_Consumption_B1-Resources_to_Consume_B1

C_Trades_to_B1 (Not in a sector)

A1_Trades_to_B1 (Not in a sector)

OUTFLOWS:
B1_Trades_to_C (Not in a sector)

Storage_Consumed_B1 = Resources_in_Storage_B1

B1_Trades_to_A1 (Not in a sector)

Population_B1(t) = Population_B1(t - dt) + (Birth_Rate_B1 + C_Migrates_to_B1 + A1_Migrates_to_B1 - Death_Rate_B1 - B1_Migrates_to_A1 - B1_Migrates_to_C) * dtINIT

Population_B1 = 100

INFLOWS:
Birth_Rate_B1 =
DELAY(ROUND(Normal_Birth_Fraction_B1*Population_B1*Birth_Rate_Multiplier_from_Consumption_B1),0.75)

C_Migrates_to_B1 (Not in a sector)

A1_Migrates_to_B1 (Not in a sector)

OUTFLOWS:
Death_Rate_B1 =
ROUND((Population_B1*Normal_Death_Fraction_B1*Death_Rate_Multiplier_from_Consumption_B1) * (1+Internal_Conflict_B1)+ Warfare_Deaths_B1)

B1_Migrates_to_A1 (Not in a sector)

B1_Migrates_to_C (Not in a sector)

Birth_Rate_Multiplier_from_Consumption_B1 = IF
Consumption_Delay_from_Birth_Rate_Multiplier_B1 < 1
THEN
Consumption_Delay_from_Birth_Rate_Multiplier_B1
ELSE
2.5*Consumption_Delay_from_Birth_Rate_Multiplier_B1-1.5

Circumscription_B1 = IF
Consumption__per_Capita_B1 >= 1
THEN
0.1024*exp((7.67*Population_Density_B1)-7.93)
ELSE
0.1024*exp((7.67*Population_Density_B1)-(7.93*Consumption__per_Capita_B1))

Consumption_Delay_from_Birth_Rate_Multiplier_B1 =
DELAY(Consumption__per_Capita_B1,0.75)

Consumption__per_Capita_B1 = IF
Population_B1 >0
THEN
IF
C_Overpowers_B1 = 0 AND A1_Overpowers_B1 = 0
THEN
MIN(((Resources_to_Consume_B1+Resources_in_Storage_B1)/Population_B1), 2)
ELSE

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MIN((Resources_to_Consume_B1)/Population_B1, .995)
ELSE
0

Death_Rate_Multiplier_from_Consumption_B1 = IF Consumption__per_Capita_B1 < 1
THEN
-9*Consumption__per_Capita_B1+10
ELSE
IF Consumption__per_Capita_B1 < 2
THEN
-0.2*Consumption__per_Capita_B1+1.2
ELSE
0.8

Environmental_Degradation_B1 = -0.5*DELAY(Intensification_B1, 1)+1.5

HarvestingRate__Multiplier_from_Intensification_B1 = MAX(1.05,
(0.85+0.2*Intensification_B1))

Harvesting_Rate_Multiplier_from_Population_Density_B1 = IF
(Population_Density_B1 < 1)
THEN
1
ELSE (-0.5*Population_Density_B1+1.5)

Harvesting_Rate_Multiplier_from_Technology_B1 = IF
Technology_B1 <= 0
THEN
1
ELSE
(1/(1+89*EXP(-1.8*Technology_B1)))+1

Intensification_B1 = IF
Population_Density_B1 <= 1
THEN
1
ELSE
(1/(2*(1+12000000*EXP(-13*Population_Density_B1))))+1

Internal_Conflict_B1 = IF Consumption__per_Capita_B1 < 1
THEN
-0.95*Consumption__per_Capita_B1+1
ELSE
IF Consumption__per_Capita_B1 < 2
THEN
-0.05*Consumption__per_Capita_B1+0.1
ELSE
0
```

Land_B1 = 100

Migration_Multiplier_B1 = IF (Consumption__per_Capita_B1 < 0.8)
THEN
((-0.5*Consumption__per_Capita_B1+0.5) + 0.5*Internal_Conflict_B1)
ELSE IF
(Consumption__per_Capita_B1 > 1.2)
THEN (0 + 0.5*Internal_Conflict_B1)
ELSE ((-0.25*Consumption__per_Capita_B1+0.3) + 0.5*Internal_Conflict_B1)

Normal_Birth_Fraction_B1 = NORMAL(0.04, 0.01)

Normal_Death_Fraction_B1 = NORMAL(0.02, 0.005)

Population_Density_B1 = Population_B1/Land_B1

Resource_Maximum_B1 = 400

Resource_Reproduction_Fraction_B1 = NORMAL(1.2, 0.05)

SOCIETY B2

Available_Resources_B2(t) = Available_Resources_B2(t - dt) +
(Resource__Reproduction_Rate_B2 - Harvesting_Rate_B2) * dtINIT

Available_Resources_B2 = 200 [for t = 0]

INFLOWS:
Resource__Reproduction_Rate_B2 =
(Environmental__Degradation_B2)*(Normal_Resource_Reproduction_Fraction_B2*200
*(1-(Available_Resources_B2/Resource_Maximum_B2)))

OUTFLOWS:
Harvesting_Rate_B2 =
MIN(Population_B2*Harvesting_Rate__Multiplier_from_Intensification_B2*Harvest
ing_Rate_Multiplier_from_Population_Density_B2*Harvesting_Rate_Multiplier_fro
m_Technology_B2, Available_Resources_B2)

Population_B2(t) = Population_B2(t - dt) + (Birth_Rate_B2 + C_Migrates_to_B2
+ A2_Migrates_to_B2 - Death_Rate_B2 - B2_Migrates_to_A2 - B2_Migrates_to_C) *
dtINIT

Population_B2 = 100 [for t = 0]

INFLOWS:
Birth_Rate_B2 =
DELAY(ROUND(Normal_Birth_Fraction_B2*Population_B2*Birth_Rate_Multiplier_from
_Consumption_B2),0.75)

C_Migrates_to_B2 (Not in a sector)

A2_Migrates_to_B2 (Not in a sector)

OUTFLOWS:
Death_Rate_B2 =
ROUND((Population_B2*Normal_Death_Fraction_B2*Death_Rate_Multiplier_from_Consumption_B2) * (1+Internal_Conflict_B2)+ Warfare_Deaths_B2)

B2_Migrates_to_A2 (Not in a sector)

B2_Migrates_to_C (Not in a sector)

Resources_Available__for_Consumption_B2(t) =
Resources_Available__for_Consumption_B2(t - dt) + (Harvesting_Rate_B2 - Resources_to_Store_B2 - Resources_to_Consume_B2) * dtINIT

Resources_Available__for_Consumption_B2 = 100 [for t = 0]

INFLOWS:
Harvesting_Rate_B2 =
MIN(Population_B2*Harvesting_Rate__Multiplier_from_Intensification_B2*Harvesting_Rate_Multiplier_from_Population_Density_B2*Harvesting_Rate_Multiplier_from_Technology_B2, Available_Resources_B2)

OUTFLOWS:
Resources_to_Store_B2 = IF
Technology_B2 < 1
THEN
0
ELSE
Resources_Available__for_Consumption_B2-Resources_to_Consume_B2

Resources_to_Consume_B2 = IF
Technology_B2 < 1
THEN
MIN(Resources_Available__for_Consumption_B2, 2*Population_B2)
ELSE
MIN(Population_B2, Resources_Available__for_Consumption_B2)

Resources_in_Storage_B2(t) = Resources_in_Storage_B2(t - dt) + (Resources_to_Store_B2 + C_Trades_to_B2 + A2_Trades_to_B2 - B2_Trades_To_C - Storage_Consumed_B2 - B2_Trades_to_A2) * dtINIT

Resources_in_Storage_B2 = 0 [for t = 0]

INFLOWS:
Resources_to_Store_B2 = IF

```
Technology_B2 < 1
THEN
0
ELSE
Resources_Available__for_Consumption_B2-Resources_to_Consume_B2

C_Trades_to_B2  (Not in a sector)

A2_Trades_to_B2  (Not in a sector)

OUTFLOWS:
B2_Trades_To_C  (Not in a sector)

Storage_Consumed_B2 = Resources_in_Storage_B2

B2_Trades_to_A2  (Not in a sector)

Birth_Rate_Multiplier_from_Consumption_B2 = IF
Consumption_Delay_for_Birth_Rate_Multiplier_B2 < 1
THEN
Consumption_Delay_for_Birth_Rate_Multiplier_B2
ELSE
2.5*Consumption_Delay_for_Birth_Rate_Multiplier_B2-1.5

Circumscription_B2 = IF
Consumption__per_Capita_B2 >= 1
THEN
0.1024*exp((7.67*Population_Density_B2)-7.93)
ELSE
0.1024*exp((7.67*Population_Density_B2)-(7.93*Consumption__per_Capita_B2))

Consumption_Delay_for_Birth_Rate_Multiplier_B2 =
DELAY(Consumption__per_Capita_B2,0.75)

Consumption__per_Capita_B2 = IF
Population_B2 >0
THEN
IF
C_Overpowers_B2 = 0 AND  A2_Overpowers_B2 = 0
THEN
MIN(((Resources_to_Consume_B2+Resources_in_Storage_B2)/Population_B2), 2)
ELSE
MIN((Resources_to_Consume_B2)/Population_B2, .995)
ELSE
0

Death_Rate_Multiplier_from_Consumption_B2 = IF Consumption__per_Capita_B2 < 1
THEN
-9*Consumption__per_Capita_B2+10
```

```
ELSE
IF Consumption__per_Capita_B2 < 2
THEN
-0.2*Consumption__per_Capita_B2+1.2
ELSE
0.8

Environmental__Degradation_B2 = -0.5*DELAY(Intensification_B2, 1)+1.5

Harvesting_Rate_Multiplier_from_Population_Density_B2 = IF
(Population_Density_B2 < 1) THEN 1 ELSE (-0.5*Population_Density_B2+1.5)

Harvesting_Rate_Multiplier_from_Technology_B2 = IF
Technology_B2 <= 0
THEN
1
ELSE
(1/(1+89*EXP(-1.8*Technology_B2)))+1

Harvesting_Rate__Multiplier_from_Intensification_B2 = MAX(1.05,
(0.85+0.2*Intensification_B2))

Intensification_B2 = IF
Population_Density_B2 <= 1
THEN
1
ELSE
(1/(2*(1+12000000*EXP(-13*Population_Density_B2))))+1

Internal_Conflict_B2 = IF Consumption__per_Capita_B2 < 1
THEN
-0.95*Consumption__per_Capita_B2+1
ELSE
IF Consumption__per_Capita_B2 < 2
THEN
-0.05*Consumption__per_Capita_B2+0.1
ELSE
0

Land_B2 = 100

Migration_Multiplier_B2 = IF (Consumption__per_Capita_B2 < 0.8)
THEN ((-0.5*Consumption__per_Capita_B2+0.5) + 0.5*Internal_Conflict_B2)
ELSE IF (Consumption__per_Capita_B2 > 1.2)
THEN (0 + 0.5*Internal_Conflict_B2)
ELSE ((-0.25*Consumption__per_Capita_B2+0.3) + 0.5*Internal_Conflict_B2)

Normal_Birth_Fraction_B2 = NORMAL(0.04, 0.01)
```

Normal_Death_Fraction_B2 = NORMAL(0.02, 0.005)

Normal_Resource_Reproduction_Fraction_B2 = NORMAL(1.2, 0.05)

Population_Density_B2 = Population_B2/Land_B2

Resource_Maximum_B2 = 400

SOCIETY C

Available_Resources_C(t) = Available_Resources_C(t - dt) +
(Resource_Reproduction_Rate_C - Harvesting_Rate_C) * dtINIT

Available_Resources_C = 200 [for t = 0]

INFLOWS:
Resource_Reproduction_Rate_C =
Environmental_Degradation_C*Normal_Resource_Reproduction_Fraction_C*200*(1-
(Available_Resources_C/Resource__Maximum_C))

OUTFLOWS:
Harvesting_Rate_C =
MIN(Population_C*Harvesting_Rate_Multiplier_from_Intensification_C*Harvesting
_Rate_Multiplier_from_Population_Density_C *
Harvesting_Rate_Multiplier_from_Technology_C, Available_Resources_C)

Resources_Available_for_Consumption_C(t) =
Resources_Available_for_Consumption_C(t - dt) + (Harvesting_Rate_C -
Resources_to_Store_C - Resources_to_Consume_C) * dtINIT

Resources_Available_for_Consumption_C = 100 [for t = 0]

INFLOWS:
Harvesting_Rate_C =
MIN(Population_C*Harvesting_Rate_Multiplier_from_Intensification_C*Harvesting
_Rate_Multiplier_from_Population_Density_C *
Harvesting_Rate_Multiplier_from_Technology_C, Available_Resources_C)

OUTFLOWS:
Resources_to_Store_C = IF
Technology_C < 1
THEN
0
ELSE
Resources_Available_for_Consumption_C-Resources_to_Consume_C

Resources_to_Consume_C = IF
Technology_C < 1

THEN
MIN(Resources_Available_for_Consumption_C, 2*Population_C)
ELSE
MIN(Population_C,Resources_Available_for_Consumption_C)

Resources_in_Storage_C(t) = Resources_in_Storage_C(t - dt) + (Resources_to_Store_C + B1_Trades_to_C + B2_Trades_To_C - C_Trades_to_B2 - Storage_Consumed_C - C_Trades_to_B1) * dtINIT

Resources_in_Storage_C = 0 [for t = 0]

INFLOWS:
Resources_to_Store_C = IF
Technology_C < 1
THEN
0
ELSE
Resources_Available_for_Consumption_C-Resources_to_Consume_C

B1_Trades_to_C (Not in a sector)

B2_Trades_To_C (Not in a sector)

OUTFLOWS:
C_Trades_to_B2 (Not in a sector)

Storage_Consumed_C = Resources_in_Storage_C

C_Trades_to_B1 (Not in a sector)

Population_C(t) = Population_C(t - dt) + (Birth_Rate_C + B2_Migrates_to_C + B1_Migrates_to_C - Death_Rate_C - C_Migrates_to_B2 - C_Migrates_to_B1) * dtINIT

Population_C = 100 [for t = 0]

INFLOWS:
Birth_Rate_C =
DELAY(ROUND(Normal_Birth_Fraction_C*Population_C*Birth_Rate_Multiplier_from_Consumption_C),0.75)

B2_Migrates_to_C (Not in a sector)

B1_Migrates_to_C (Not in a sector)

OUTFLOWS:
Death_Rate_C =
ROUND((Population_C*Normal_Death_Fraction_C*Death_Rate_Multiplier_from_Consumption_C*(1+Internal_Conflict_C)) + Warfare_Deaths_C)

C_Migrates_to_B2 (Not in a sector)

C_Migrates_to_B1 (Not in a sector)

Birth_Rate_Multiplier_from_Consumption_C = IF
Consumption_Delay_for_Birth_Rate_Multiplier_C < 1
THEN
Consumption_Delay_for_Birth_Rate_Multiplier_C
ELSE
2.5*Consumption_Delay_for_Birth_Rate_Multiplier_C-1.5

Circumscription_C = IF
Consumption_Per_Capita_C >= 1
THEN
0.1024*exp((7.67*Population_Density_C)-7.93)
ELSE
0.1024*exp((7.67*Population_Density_C)-(7.93*Consumption_Per_Capita_C))

Consumption_Delay_for_Birth_Rate_Multiplier_C =
DELAY(Consumption_Per_Capita_C, 0.75)

Consumption_Per_Capita_C = IF
Population_C >0
THEN
IF
B2_Overpowers_C = 0 AND B1_Overpowers_C = 0
THEN
MIN(((Resources_to_Consume_C+Resources_in_Storage_C)/Population_C), 2)
ELSE
MIN((Resources_to_Consume_C)/Population_C, .995)
ELSE
0

Death_Rate_Multiplier_from_Consumption_C = IF Consumption_Per_Capita_C < 1
THEN
-9*Consumption_Per_Capita_C+10
ELSE
IF Consumption_Per_Capita_C < 2
THEN
-0.2*Consumption_Per_Capita_C+1.2
ELSE
0.8

Environmental_Degradation_C = -0.5*DELAY(Intensification_C_, 1)+1.5

Harvesting_Rate_Multiplier_from_Intensification_C = MAX(1.05,
(0.85+0.2*Intensification_C_))

```
Harvesting_Rate_Multiplier_from_Population_Density_C = IF
(Population_Density_C < 1)
THEN
1
ELSE (-0.5*Population_Density_C+1.5)

Harvesting_Rate_Multiplier_from_Technology_C = IF
Technology_C <= 0
THEN
1
ELSE
(1/(1+89*EXP(-1.8*Technology_C)))+1

Intensification_C_ = IF
Population_Density_C <= 1
THEN
1
ELSE
(1/(2*(1+12000000*EXP(-13*Population_Density_C))))+1

Internal_Conflict_C = IF Consumption_Per_Capita_C < 1
THEN
-0.95*Consumption_Per_Capita_C+1
ELSE
IF Consumption_Per_Capita_C < 2
THEN
-0.05*Consumption_Per_Capita_C+0.1
ELSE
0

Land_C = 100

Migration_Multiplier_C = IF (Consumption_Per_Capita_C < 0.8)
THEN
((-0.5*Consumption_Per_Capita_C+0.5) + 0.5*Internal_Conflict_C)
ELSE IF
(Consumption_Per_Capita_C > 1.2)
THEN 0.5*Internal_Conflict_C
ELSE ((-0.25*Consumption_Per_Capita_C+0.3) + 0.5*Internal_Conflict_C)

Normal_Birth_Fraction_C = NORMAL (0.04, 0.01)

Normal_Death_Fraction_C = NORMAL(0.02, 0.005)

Normal_Resource_Reproduction_Fraction_C = NORMAL(1.2, 0.05)

Population_Density_C = Population_C/Land_C

Resource__Maximum_C = 400
```

Variables Not in a Sector

Technology_A1(t) = Technology_A1(t - dt) + (Tech_Growth_A1) * dtINIT

Technology_A1 = 0 [for t = 0]

INFLOWS:
Tech_Growth_A1 = IF
(Population_A1 > 0)
THEN
IF
(Deaths_from_Starvation_A1 > 0)
THEN
((Warfare_Deaths_A1/Population_A1) * 0.2) +
((Deaths_from_Starvation_A1/Population_A1) * 0.2) + B1_Tech_DIFFUSE_A1
ELSE
((Warfare_Deaths_A1/Population_A1) * 0.2) + B1_Tech_DIFFUSE_A1
ELSE
0

Technology_A2(t) = Technology_A2(t - dt) + (Tech_Growth_A2) * dtINIT

Technology_A2 = 0 [for t = 0]

INFLOWS:
Tech_Growth_A2 = IF
(Population_A2 > 0)
THEN
IF
(Deaths_from_Starvation_A2 > 0)
THEN
((Warfare_Deaths_A2/Population_A2) * 0.2) +
((Deaths_from_Starvation_A2/Population_A2) * 0.2) + B2_Tech_DIFFUSE_A2
ELSE
((Warfare_Deaths_A2/Population_A2) * 0.2) + B2_Tech_DIFFUSE_A2
ELSE
0

Technology_B1(t) = Technology_B1(t - dt) + (Tech_Growth_B1) * dtINIT

Technology_B1 = 0 [for t = 0]

INFLOWS:
Tech_Growth_B1 = IF
(Population_B1 > 0)
THEN
IF

```
(Deaths_from_Starvation_B1 > 0)
THEN
((Warfare_Deaths_B1/Population_B1) * 0.2) +
((Deaths_from_Starvation_B1/Population_B1) * 0.2) + C_Tech_DIFFUSE_B1 +
A1_Tech_DIFFUSE_B1
ELSE
((Warfare_Deaths_B1/Population_B1) * 0.2) + C_Tech_DIFFUSE_B1 +
A1_Tech_DIFFUSE_B1
ELSE
0

Technology_B2(t) = Technology_B2(t - dt) + (Tech_Growth_B2) * dtINIT
Technology_B2 = 0  [for t = 0]

INFLOWS:
Tech_Growth_B2 = IF
(Population_B2 > 0 )
THEN
IF
(Deaths_from_Starvation_B2 > 0)
THEN
((Warfare_Deaths_B2/Population_B2) * 0.2) +
((Deaths_from_Starvation_B2/Population_B2) * 0.2) + C_Tech_DIFFUSE_B2 +
A2_Tech_DIFFUSE_B2
ELSE
((Warfare_Deaths_B2/Population_B2) * 0.2) + C_Tech_DIFFUSE_B2 +
A2_Tech_DIFFUSE_B2
ELSE
0

Technology_C(t) = Technology_C(t - dt) + (Tech_Growth_C) * dtINIT

Technology_C = 0

INFLOWS:
Tech_Growth_C = IF
(Population_C > 0)
THEN
IF
(Deaths_from_Starvation_C > 0)
THEN
((Warfare_Deaths_C/Population_C) * 0.2) +
((Deaths_from_Starvation_C/Population_C) * 0.2) + B1_Tech_DIFFUSE_C +
B2_Tech_DIFFUSE_C
ELSE
((Warfare_Deaths_C/Population_C) * 0.2) + B1_Tech_DIFFUSE_C +
B2_Tech_DIFFUSE_C
ELSE
0
```

War_Growth_Factor = 0.0005
[This factor is used in the warfare growth rate variables to scale the amount of conflict to reasonable levels of warfare fatalities]

Warfare_B1_and_A1(t) = Warfare_B1_and_A1(t - dt) +
(Warfare_B1_and_A1_Growth_Rate - Warfare_B1_and_A1_Decay_Rate) * dtINIT

Warfare_B1_and_A1 = 0 [for t = 0]

INFLOWS:
Warfare_B1_and_A1_Growth_Rate = IF
Population_A1 > 0 AND Population_B2 > 0
THEN
IF
B1_Overpowers_A1 = 0 AND A1_Overpowers_B1 = 0
THEN
((Circumscription_A1+Circumscription_B1)/2)*War_Growth_Factor*Population_B2
*Population_A1
ELSE
0
ELSE
0

OUTFLOWS:
Warfare_B1_and_A1_Decay_Rate = 0.95*Warfare_B1_and_A1

Warfare_B1_and_A1_Adj(t) = Warfare_B1_and_A1_Adj(t - dt) +
(Warfare_B1_and_A1_Growth_Rate_Adj - Warfare_B1_and_A1_Decay_Rate_Adj) *
dtINIT

Warfare_B1_and_A1_Adj = 0 [for t = 0]

[This variable adjusts the intensity of the warfare between A1 and B1 when the conflict between B1 and C takes precedence (for instance the impact on A1 will be less when this is the case as it experiences partial "exclusion" from conflict). The same explanation applies to the other adjusted variables below.]

INFLOWS:
Warfare_B1_and_A1_Growth_Rate_Adj =
IF
Population_A1 > 0 AND Population_B2 > 0
THEN
IF
B1_Overpowers_A1 = 0 AND A1_Overpowers_B1 = 0
THEN
((Circumscription_A1+Circumscription_B1)/2)*War_Growth_Factor
*(Population_B2-Warfare_Deaths_B1_from_C)*Population_A1

```
ELSE
0
ELSE
0

OUTFLOWS:
Warfare_B1_and_A1_Decay_Rate_Adj = 0.95*Warfare_B1_and_A1_Adj

Warfare_B2_and_A2(t) = Warfare_B2_and_A2(t - dt) +
(Warfare_B2_and_A2_Growth_Rate - Warfare_B2_and_A2_Decay_Rate) * dtINIT

Warfare_B2_and_A2 = 0  [for t = 0]

INFLOWS:
Warfare_B2_and_A2_Growth_Rate = IF
Population_A2 > 0 AND Population_B2 > 0
THEN
IF
B2_Overpowers_A2 = 0 AND A2_Overpowers_B2 = 0
THEN
((Circumscription_A2+Circumscription_B2)/2)*War_Growth_Factor*Population_B2
*Population_A2
ELSE
0
ELSE
0

OUTFLOWS:
Warfare_B2_and_A2_Decay_Rate = 0.95*Warfare_B2_and_A2

Warfare_B2_and_A2_Adj(t) = Warfare_B2_and_A2_Adj(t - dt) +
(Warfare_B2_and_A2_Growth_Rate_Adj - Warfare_B2_and_A2_Decay_Rate_Adj) *
dtINIT

Warfare_B2_and_A2_Adj = 0  [for t = 0]

INFLOWS:
Warfare_B2_and_A2_Growth_Rate_Adj =
IF
Population_A2 > 0 AND Population_B2 > 0
THEN
IF
B2_Overpowers_A2 = 0 AND A2_Overpowers_B2 = 0
THEN
((Circumscription_A2+Circumscription_B2)/2)*War_Growth_Factor*
(Population_B2-Warfare_Deaths_B2_from_C)*Population_A2
ELSE
0
ELSE
```

```
0

OUTFLOWS:
Warfare_B2_and_A2_Decay_Rate_Adj = 0.95*Warfare_B2_and_A2_Adj

Warfare_C_and_B1(t) = Warfare_C_and_B1(t - dt) +
(Warfare_C_and_B1_Growth_Rate - Warfare_C_and_B1_Decay_Rate) * dtINIT

Warfare_C_and_B1 = 0  [for t = 0]

INFLOWS:
Warfare_C_and_B1_Growth_Rate =
IF
Population_C > 0 AND Population_B2 > 0
THEN
IF
C_Overpowers_B1 = 0 AND B1_Overpowers_C = 0
THEN
((Circumscription_B1+Circumscription_C)/2)*War_Growth_Factor*Population_C
*Population_B2
ELSE
0
ELSE
0

OUTFLOWS:
Warfare_C_and_B1_Decay_Rate = 0.95*Warfare_C_and_B1

Warfare_C_and_B1_Adj_B1(t) = Warfare_C_and_B1_Adj_B1(t - dt) +
(Warfare_C_and_B1_Growth_Rate_Adj_B1 - Warfare_C_and_B1_Decay_Rate_Adj_B1) *
dtINIT

Warfare_C_and_B1_Adj_B1 = 0  [for t = 0]

INFLOWS:
Warfare_C_and_B1_Growth_Rate_Adj_B1 =
IF
Population_C > 0 AND Population_B2 > 0
THEN
IF
C_Overpowers_B1 = 0 AND B1_Overpowers_C = 0
THEN
((Circumscription_B1+Circumscription_C)/2)*War_Growth_Factor*Population_C
*(Population_B2-Warfare_Deaths_B1_from_A1)
ELSE
0
ELSE
0
```

```
OUTFLOWS:
Warfare_C_and_B1_Decay_Rate_Adj_B1 = 0.95*Warfare_C_and_B1_Adj_B1

Warfare_C_and_B1_Adj_C(t) = Warfare_C_and_B1_Adj_C(t - dt) +
(Warfare_C_and_B1_Growth_Rate_Adj_C - Warfare_C_and_B1_Decay_Rate_Adj_C) *
dtINIT

Warfare_C_and_B1_Adj_C = 0  [for t = 0]

INFLOWS:
Warfare_C_and_B1_Growth_Rate_Adj_C =
IF
Population_C > 0 AND Population_B2 > 0
THEN
IF
C_Overpowers_B1 = 0 AND B1_Overpowers_C = 0
THEN
((Circumscription_B1+Circumscription_C)/2)*War_Growth_Factor*(Population_C-
Warfare_Deaths_C_from_B2)*Population_B2
ELSE
0
ELSE
0

OUTFLOWS:
Warfare_C_and_B1_Decay_Rate_Adj_C = 0.95*Warfare_C_and_B1_Adj_C

Warfare_C_and_B2(t) = Warfare_C_and_B2(t - dt) +
(Warfare_C_and_B2_Growth_Rate - Warfare_C_and_B2_Decay_Rate) * dtINIT
Warfare_C_and_B2 = 0

INFLOWS:
Warfare_C_and_B2_Growth_Rate =
IF
Population_C > 0 AND Population_B2 > 0
THEN
IF
C_Overpowers_B2 = 0 AND B2_Overpowers_C = 0
THEN
((Circumscription_B2+Circumscription_C)/2)*War_Growth_Factor*Population_C
*Population_B2
ELSE
0
ELSE
0

OUTFLOWS:
Warfare_C_and_B2_Decay_Rate = 0.95*Warfare_C_and_B2
```

Warfare_C_and_B2_Adj_B2(t) = Warfare_C_and_B2_Adj_B2(t - dt) +
(Warfare_C_and_B2_Growth_Rate_Adj_B2 - Warfare_C_and_B2_Decay_Rate_Adj_B2) *
dtINIT

Warfare_C_and_B2_Adj_B2 = 0 [for t = 0]

INFLOWS:
Warfare_C_and_B2_Growth_Rate_Adj_B2 =
IF
Population_C > 0 AND Population_B2 > 0
THEN
IF
C_Overpowers_B2 = 0 AND B2_Overpowers_C = 0
THEN
((Circumscription_B2 +
Circumscription_C)/2)*War_Growth_Factor*Population_C*(Population_B2-
Warfare_Deaths_B2_from_A2)
ELSE
0
ELSE
0

OUTFLOWS:
Warfare_C_and_B2_Decay_Rate_Adj_B2 = 0.95*Warfare_C_and_B2_Adj_B2

Warfare_C_and_B2_Adj_C(t) = Warfare_C_and_B2_Adj_C(t - dt) +
(Warfare_C_and_B2_Growth_Rate_Adj_C - Warfare_C_and_B2_Decay_Rate_Adj_C) *
dtINIT

Warfare_C_and_B2_Adj_C = 0 [for t = 0]

INFLOWS:
Warfare_C_and_B2_Growth_Rate_Adj_C =
IF
Population_C > 0 AND Population_B2 > 0
THEN
IF
C_Overpowers_B2 = 0 AND B2_Overpowers_C = 0
THEN
((Circumscription_B2 + Circumscription_C)/2)*War_Growth_Factor*(Population_C-
Warfare_Deaths_C_from_B1)*Population_B2
ELSE
0
ELSE
0

OUTFLOWS:
Warfare_C_and_B2_Decay_Rate_Adj_C = 0.95*Warfare_C_and_B2_Adj_C

[Flows between sectors (societies)]

```
A1_Migrates_to_B1 = IF
Migration_Multiplier_A1 > NORMAL((0.1 * (1+ Circumscription_B1)), 0.025)
THEN
(Round(Population_A1*Migration_Multiplier_A1))
ELSE
0
OUTFLOW FROM:  Population_A1  (IN SECTOR:  Society A1)
INFLOW TO:  Population_B1     (IN SECTOR:  Society B1)

A1_Trades_to_B1 = (Resources_in_Storage_A1) * (B1_Gets_From_A1)
OUTFLOW FROM:  Resources_in_Storage_A1    (IN SECTOR:  Society A1)
INFLOW TO:  Resources_in_Storage_B1 (IN SECTOR:  Society B1)

A2_Migrates_to_B2 = IF
Migration_Multiplier_A2 > NORMAL((0.1 * (1+ Circumscription_B2)), 0.025)
THEN
(Round(Population_A2*Migration_Multiplier_A2))
ELSE
0
OUTFLOW FROM:  Population_A2  (IN SECTOR:  Society A2)
INFLOW TO:  Population_B2     (IN SECTOR:  Society B2)

A2_Trades_to_B2 = (Resources_in_Storage_A2) * (B2_Gets_From_A2)
OUTFLOW FROM:  Resources_in_Storage_A2    (IN SECTOR:  Society A2)
INFLOW TO:  Resources_in_Storage_B2 (IN SECTOR:  Society B2)

B1_Migrates_to_A1 = IF
Migration_Multiplier_B1 > NORMAL((0.1 * (1+ Circumscription_A1)), 0.025)
THEN
(Round(Population_B1*Migration_Multiplier_B1))
ELSE
0
OUTFLOW FROM:  Population_B1  (IN SECTOR:  Society B1)
INFLOW TO:  Population_A1     (IN SECTOR:  Society A1)

B1_Migrates_to_C = IF
Migration_Multiplier_B1 > NORMAL((0.1 * (1+ Circumscription_C)), 0.025)
THEN
(Round(Population_B1*Migration_Multiplier_B1))
ELSE
0
OUTFLOW FROM:  Population_B1  (IN SECTOR:  Society B1)
INFLOW TO:  Population_C      (IN SECTOR:  Society C)

B1_Trades_to_A1 =
IF Warfare_Advantage_Society_A1 > Warfare_Advantage_Society_C
```

```
THEN
A1_Gets_From_B1*Resources_in_Storage_B1
ELSE
A1_Gets_From_B1*Resources_in_Storage_B1*(1-C_Gets_From_B1)
OUTFLOW FROM:  Resources_in_Storage_B1    (IN SECTOR:  Society B1)
INFLOW TO:  Resources_in_Storage_A1 (IN SECTOR:  Society A1)

B1_Trades_to_C =
IF Warfare_Advantage_Society_C > Warfare_Advantage_Society_A1
THEN
C_Gets_From_B1*Resources_in_Storage_B1
ELSE
C_Gets_From_B1*Resources_in_Storage_B1*(1-A1_Gets_From_B1)
OUTFLOW FROM:  Resources_in_Storage_B1    (IN SECTOR:  Society B1)
INFLOW TO:  Resources_in_Storage_C  (IN SECTOR:  Society C)

B2_Migrates_to_A2 = IF
Migration_Multiplier_B2 > NORMAL((0.1 * (1+ Circumscription_A2)), 0.025)
THEN
(Round(Population_B2*Migration_Multiplier_B2))
ELSE
0
OUTFLOW FROM:  Population_B2  (IN SECTOR:  Society B2)
INFLOW TO:  Population_A2     (IN SECTOR:  Society A2)

B2_Migrates_to_C = IF
Migration_Multiplier_B2 > NORMAL((0.1 * (1+ Circumscription_C)), 0.025)
THEN
(Round(Population_B2*Migration_Multiplier_B2))
ELSE
0
OUTFLOW FROM:  Population_B2  (IN SECTOR:  Society B2)
INFLOW TO:  Population_C      (IN SECTOR:  Society C)

B2_Trades_to_A2 =
IF Warfare_Advantage_Society_A2 > Warfare_Advantage_Society_C
THEN
A2_Gets_From_B2*Resources_in_Storage_B2
ELSE
A2_Gets_From_B2*Resources_in_Storage_B2*(1-C_Gets_From_B2)
OUTFLOW FROM:  Resources_in_Storage_B2    (IN SECTOR:  Society B2)
INFLOW TO:  Resources_in_Storage_A2 (IN SECTOR:  Society A2)

B2_Trades_To_C =
IF Warfare_Advantage_Society_C > Warfare_Advantage_Society_A2
THEN
C_Gets_From_B2*Resources_in_Storage_B2
ELSE
C_Gets_From_B2*Resources_in_Storage_B2*(1-A2_Gets_From_B2)
```

```
OUTFLOW FROM:  Resources_in_Storage_B2    (IN SECTOR:  Society B2)
INFLOW TO:  Resources_in_Storage_C  (IN SECTOR:  Society C)

C_Migrates_to_B1 = IF
Migration_Multiplier_C > NORMAL((0.1 * (1+ Circumscription_B1)), 0.025)
THEN
(Round(Population_C*Migration_Multiplier_C))
ELSE
0
OUTFLOW FROM:  Population_C   (IN SECTOR:  Society C)
INFLOW TO:  Population_B1     (IN SECTOR:  Society B1)

C_Migrates_to_B2 = IF
Migration_Multiplier_C > NORMAL((0.1 * (1+ Circumscription_B2)), 0.025)
THEN
(Round(Population_C*Migration_Multiplier_C))
ELSE
0
OUTFLOW FROM:  Population_C   (IN SECTOR:  Society C)
INFLOW TO:  Population_B2     (IN SECTOR:  Society B2)

C_Trades_to_B1 =
IF Warfare_Advantage_Society_B1 > Warfare_Advantage_Society_B2
THEN
B1_Gets_from_C*Resources_in_Storage_C
ELSE
B1_Gets_from_C*Resources_in_Storage_C*(1-B2_Gets_From_C)
OUTFLOW FROM:  Resources_in_Storage_C     (IN SECTOR:  Society C)
INFLOW TO:  Resources_in_Storage_B1 (IN SECTOR:  Society B1)

C_Trades_to_B2 =
IF Warfare_Advantage_Society_B2 > Warfare_Advantage_Society_B1
THEN
B2_Gets_From_C*Resources_in_Storage_C
ELSE
B2_Gets_From_C*Resources_in_Storage_C*(1-B1_Gets_from_C)
OUTFLOW FROM:  Resources_in_Storage_C     (IN SECTOR:  Society C)
INFLOW TO:  Resources_in_Storage_B2 (IN SECTOR:  Society B2)

A1_B1_Pop_and_Tech_Ratio = A1_Pop_DIV_B1_Pop * A1_Tech_DIV_B1_Tech

A2_B2_Pop_and_Tech_Ratio = A2_Pop_DIV_B2_Pop *A2_Tech_DIV_B2_Tech

B1_A1_Pop_and_Tech_Ratio = B1_Pop_DIV_A1_Pop * B1_Tech_DIV_A1_Tech

B1_C_Pop_and_Tech_Ratio = B1_Pop_DIV_C_Pop*B1_Tech_DIV_C_Tech

B2_A2_Pop_and_Tech_Ratio = B2_Pop_DIV_A2_Pop*B2_Tech_DIV_A2_Tech
```

```
B2_C_Pop_and_Tech_Ratio = B2_Pop_DIV_C_Pop*B2_Tech_DIV_C_Tech

C_B1_Pop_and_Tech_Ratio = C_Pop_DIV_B1_Pop*C_Tech_DIV_B1_Tech

C_B2_Pop_and_Tech_Ratio = C_Pop_DIV_B2_Pop * C_Tech_DIV_B2_Tech

A1_Exploits_B1 = B1_Trades_to_A1 - A1_Trades_to_B1

A2_Exploits_B2 = B2_Trades_to_A2 - A2_Trades_to_B2

B1_Exploits_A1 = A1_Trades_to_B1 - B1_Trades_to_A1

B1_Exploits_C = C_Trades_to_B1 - B1_Trades_to_C

B2_Exploits_A2 = A2_Trades_to_B2 - B2_Trades_to_A2

B2_Exploits_C = C_Trades_to_B2 - B2_Trades_To_C

C_Exploits_B1 = B1_Trades_to_C - C_Trades_to_B1

C_Exploits_B2 = B2_Trades_To_C - C_Trades_to_B2

A1_Gets_From_B1 = IF
Technology_A1 > 1 & Technology_B1 > 1
THEN
1/(1+1100*EXP(-7*A1_B1_Pop_and_Tech_Ratio))
ELSE
0

A2_Gets_From_B2 = IF
Technology_A2 > 1 & Technology_B2 > 1
THEN
1/(1+1100*EXP(-7*A2_B2_Pop_and_Tech_Ratio))
ELSE
0

B1_Gets_From_A1 = IF
Technology_A1 > 1 & Technology_B1 > 1
THEN
1/(1+1100*EXP(-7*B1_A1_Pop_and_Tech_Ratio))
ELSE
0

B1_Gets_from_C = IF
Technology_C > 1 & Technology_B1 > 1
THEN
1/(1+1100*EXP(-7*B1_C_Pop_and_Tech_Ratio))
ELSE
0
```

```
B2_Gets_From_A2 = IF
Technology_A2 > 1 & Technology_B2 > 1
THEN
1/(1+1100*EXP(-7*B2_A2_Pop_and_Tech_Ratio))
ELSE
0

B2_Gets_From_C = IF
Technology_C > 1 & Technology_B2 > 1
THEN
1/(1+1100*EXP(-7*B2_C_Pop_and_Tech_Ratio))
ELSE
0

C_Gets_From_B1 = IF
Technology_C > 1 & Technology_B1 > 1
THEN
1/(1+1100*EXP(-7*C_B1_Pop_and_Tech_Ratio))
ELSE
0

C_Gets_From_B2 = IF
Technology_C > 1 & Technology_B2 > 1
THEN
1/(1+1100*EXP(-7*C_B2_Pop_and_Tech_Ratio))
ELSE
0

A1_Overpowers_B1 = IF
A1_B1_Pop_and_Tech_Ratio > 1.5 AND Technology_A1 > 1 AND Technology_B1 > 1
THEN
1
ELSE
0

A2_Overpowers_B2 = IF
A2_B2_Pop_and_Tech_Ratio > 1.5 AND Technology_A2 > 1 AND Technology_B2 > 1
THEN
1
ELSE
0

B1_Overpowers_A1 = IF
B1_A1_Pop_and_Tech_Ratio >1.5 AND Technology_A1 > 1 AND Technology_B1 > 1
THEN
1
ELSE
0
```

```
B1_Overpowers_C = IF
B1_C_Pop_and_Tech_Ratio > 1.5 AND Technology_C > 1 AND Technology_B1 > 1
THEN
1
ELSE
0

B2_Overpowers_A2 = IF
B2_A2_Pop_and_Tech_Ratio >1.5 AND Technology_A2 > 1 AND Technology_B2 > 1
THEN
1
ELSE
0

B2_Overpowers_C = IF
B2_C_Pop_and_Tech_Ratio > 1.5 AND Technology_C > 1 AND Technology_B2 > 1
THEN
1
ELSE
0

C_Overpowers_B1 = IF
C_B1_Pop_and_Tech_Ratio >1.5 AND Technology_C > 1 AND Technology_B1 > 1
THEN
1
ELSE
0

C_Overpowers_B2 = IF
C_B2_Pop_and_Tech_Ratio >1.5 AND Technology_C > 1 AND Technology_B2 > 1
THEN
1
ELSE
0

A1_Pop_DIV_B1_Pop = IF
Population_B1 >= 1
THEN
Population_A1/Population_B1
ELSE
0

A2_Pop_DIV_B2_Pop = IF
Population_B2 >= 1
THEN
Population_A2/Population_B2
ELSE
0
```

```
B1_Pop_DIV_A1_Pop = IF
Population_A1 >= 1
THEN
Population_B1/Population_A1
ELSE
0

B1_Pop_DIV_C_Pop = IF
Population_C >= 1
THEN
Population_B1/Population_C
ELSE
0

B2_Pop_DIV_A2_Pop = IF
Population_A2 >= 1
THEN
Population_B2/Population_A2
ELSE
0

B2_Pop_DIV_C_Pop = IF
Population_C >= 1
THEN
Population_B2/Population_C
ELSE
0

C_Pop_DIV_B1_Pop = IF
Population_B1 >= 1
THEN
Population_C/Population_B1
ELSE
0

C_Pop_DIV_B2_Pop = IF
Population_B2 >= 1
THEN
Population_C/Population_B2
ELSE
0

A1_Tech_DIFFUSE_B1 = IF
A1_Overpowers_B1 = 1
THEN
(Technology_A1-Technology_B1) *0.01
ELSE
0
```

```
A2_Tech_DIFFUSE_B2 = IF
A2_Overpowers_B2 = 1
THEN
(Technology_A2-Technology_B2) *0.01
ELSE
0

B1_Tech_DIFFUSE_A1 = IF
B1_Overpowers_A1 = 1
THEN
(Technology_B1-Technology_A1) *0.01
ELSE
0

B1_Tech_DIFFUSE_C = IF
B1_Overpowers_C = 1
THEN
(Technology_B1-Technology_C) *0.01
ELSE
0

B2_Tech_DIFFUSE_A2 = IF
B2_Overpowers_A2 = 1
THEN
(Technology_B2-Technology_A2) *0.01
ELSE
0

B2_Tech_DIFFUSE_C = IF
B2_Overpowers_C = 1
THEN
(Technology_B2-Technology_C) *0.01
ELSE
0

C_Tech_DIFFUSE_B1 = IF
C_Overpowers_B1 = 1
THEN
(Technology_C-Technology_B1) *0.01
ELSE
0

C_Tech_DIFFUSE_B2 = IF
C_Overpowers_B2 = 1
THEN
(Technology_C-Technology_B2) *0.01
ELSE
0
```

```
A1_Tech_DIV_B1_Tech = IF
(Technology_A1 = 0 AND Technology_B1 = 0)
THEN
1
ELSE
IF
Technology_B1 > 0
THEN
Technology_A1/Technology_B1
ELSE
Technology_A1/0.00001

A2_Tech_DIV_B2_Tech = IF
(Technology_A2 = 0 AND Technology_B2 = 0)
THEN
1
ELSE
IF
Technology_B2 > 0
THEN
Technology_A2/Technology_B2
ELSE
Technology_A2/0.00001

B1_Tech_DIV_A1_Tech = IF
(Technology_A1 = 0 AND Technology_B1 = 0)
THEN
1
ELSE
IF
Technology_A1 > 0
THEN
Technology_B1/Technology_A1
ELSE
Technology_B1/0.00001

B1_Tech_DIV_C_Tech = IF
(Technology_C = 0 AND Technology_B1 = 0)
THEN
1
ELSE
IF
Technology_C > 0
THEN
Technology_B1/Technology_C
ELSE
Technology_B1/0.00001
```

```
B2_Tech_DIV_A2_Tech = IF
(Technology_A2 = 0 AND Technology_B2 = 0)
THEN
1
ELSE
IF
Technology_A2 > 0
THEN
Technology_B2/Technology_A2
ELSE
Technology_B2/0.00001

B2_Tech_DIV_C_Tech = IF
(Technology_C = 0 AND Technology_B2 = 0)
THEN
1
ELSE
IF
Technology_C > 0
THEN
Technology_B2/Technology_C
ELSE
Technology_B2/0.00001

C_Tech_DIV_B1_Tech = IF
(Technology_C = 0 AND Technology_B1 = 0)
THEN
1
ELSE
IF
Technology_B1 > 0
THEN
Technology_C/Technology_B1
ELSE
Technology_C/0.00001

C_Tech_DIV_B2_Tech = IF
(Technology_C = 0 AND Technology_B2 = 0)
THEN
1
ELSE
IF
Technology_B2 > 0
THEN
Technology_C/Technology_B2
ELSE
Technology_C/0.00001
```

```
Deaths_from_Starvation_A1 =
ROUND(Population_A1*Normal_Death_Fraction_A1*(1+Internal_Conflict_A1)*(1-
Death_Rate_Multiplier_from_Consumption_A1))

Deaths_from_Starvation_A2 =
ROUND(Population_A2*Normal_Death_Fraction_A2*(1+Internal_Conflict_A2)*(1-
Death_Rate_Multiplier_from_Consumption_A2))

Deaths_from_Starvation_B1 =
ROUND(Population_B1*Normal_Death_Fraction_B1*(1+Internal_Conflict_B1)*(1-
Death_Rate_Multiplier_from_Consumption_B1))

Deaths_from_Starvation_B2 =
ROUND(Population_B2*Normal_Death_Fraction_B2*(1+Internal_Conflict_B2)*(1-
Death_Rate_Multiplier_from_Consumption_B2))

Deaths_from_Starvation_C =
ROUND(Population_C*Normal_Death_Fraction_C*(1+Internal_Conflict_C)*(1-
Death_Rate_Multiplier_from_Consumption_C))

PowerA = Warfare_Advantage_Society_A1/100
PowerB = Warfare_Advantage_Society_B1/100
PowerC = Warfare_Advantage_Society_C/100

A1_Net_Exploitation = A1_Exploits_B1

A2_Net_Exploitation = A2_Exploits_B2

B1_Net_Exploitation = B1_Exploits_C + B1_Exploits_A1

B2_Net_Exploitation = B2_Exploits_C + B2_Exploits_A2

C_Net_Exploitation = C_Exploits_B1 + C_Exploits_B2

Standardized_Power_A = IF System_Tech > 0
THEN
PowerA/System_Tech
ELSE
0

Standardized_Power_B = IF System_Tech > 0
THEN
PowerB/System_Tech
ELSE
0

Standardized_Power_C = IF System_Tech > 0
THEN
PowerC/System_Tech
```

```
ELSE
0

System_Tech =
(Technology_C+Technology_A1+Technology_A2+Technology_B1+Technology_B2)/5

Warfare_Advantage_Society_A1 = Population_A1*Technology_A1

Warfare_Advantage_Society_A2 = Population_A2*Technology_A2

Warfare_Advantage_Society_B1 = Population_B1*Technology_B1

Warfare_Advantage_Society_B2 = Population_B2*Technology_B2

Warfare_Advantage_Society_C = Population_C*Technology_C

Pop_A1_minus_B1_Deaths = Population_A1-Warfare_Deaths_A1from_B1

Pop_A2_minus_B2_Deaths = Population_A2-Warfare_Deaths_A2_from_B2

Pop_B1_minus_A1_Deaths = Population_B2-Warfare_Deaths_B1_from_A1

Pop_B1_minus_C_Deaths = Population_B2-Warfare_Deaths_B1_from_C

Pop_B2_minus_A2_Deaths = Population_B2-Warfare_Deaths_B2_from_A2

Pop_B2_minus_C_Deaths = Population_B2-Warfare_Deaths_B2_from_C

Pop_C_minus_B1_Deaths = Population_C-Warfare_Deaths_C_from_B1

Pop_C_minus_B2_Deaths = Population_C-Warfare_Deaths_C_from_B2

Warfare_Deaths_A1from_B1 =
MIN(ROUND(Population_A1*Warfare_B1_and_A1*B1_A1_Pop_and_Tech_Ratio),
Population_A1)

Warfare_Deaths_A1_Adj =
MIN(ROUND(Population_A1*Warfare_B1_and_A1_Adj*B1_A1_Pop_and_Tech_Ratio),
Population_A1)

Warfare_Deaths_A1 =
IF (Circumscription_A1+Circumscription_B1) >=
(Circumscription_B1+Circumscription_C)
THEN
Warfare_Deaths_A1from_B1
ELSE
Warfare_Deaths_A1_Adj
```

```
Warfare_Deaths_A2_from_B2 =
MIN(ROUND(Population_A2*Warfare_B2_and_A2*B2_A2_Pop_and_Tech_Ratio),
Population_A2)

Warfare_Deaths_A2_Adj =
MIN(ROUND(Population_A2*Warfare_B2_and_A2_Adj*B2_A2_Pop_and_Tech_Ratio),
Population_A2)

Warfare_Deaths_A2 =
IF (Circumscription_A2+Circumscription_B2) >=
(Circumscription_B2+Circumscription_C)
THEN
Warfare_Deaths_A2_from_B2
ELSE
Warfare_Deaths_A2_Adj

Warfare_Deaths_B1_from_A1 = MIN(ROUND(Population_B1*Warfare_B1_and_A1
*A1_B1_Pop_and_Tech_Ratio), Population_B1)

Warfare_Deaths_B1_from_A1_Adj = MIN(ROUND(Population_B1*Warfare_B1_and_A1_Adj
*A1_B1_Pop_and_Tech_Ratio), Population_B1)

Warfare_Deaths_B1_from_C = MIN(ROUND(Population_B1*Warfare_C_and_B1 *
C_B1_Pop_and_Tech_Ratio), Population_B1)

Warfare_Deaths_B1_from_C_Adj =
MIN(ROUND(Population_B1*Warfare_C_and_B1_Adj_B1 * C_B1_Pop_and_Tech_Ratio),
Population_B1)

Warfare_Deaths_B1 =
IF (Circumscription_B1+Circumscription_C) >
(Circumscription_A1+Circumscription_B1)
THEN
Warfare_Deaths_B1_from_C + Warfare_Deaths_B1_from_A1_Adj
ELSE IF (Circumscription_B1+Circumscription_C) <
(Circumscription_A1+Circumscription_B1)
THEN
Warfare_Deaths_B1_from_A1 + Warfare_Deaths_B1_from_C_Adj
ELSE
Warfare_Deaths_B1_from_A1+Warfare_Deaths_B1_from_C

Warfare_Deaths_B2_from_A2 = MIN(ROUND(Population_B2*Warfare_B2_and_A2 *
A2_B2_Pop_and_Tech_Ratio), Population_B2)

Warfare_Deaths_B2_from_A2_Adj = MIN(ROUND(Population_B2*Warfare_B2_and_A2_Adj
* A2_B2_Pop_and_Tech_Ratio), Population_B2)

Warfare_Deaths_B2_from_C = MIN(ROUND(Population_B2*Warfare_C_and_B2 *
C_B2_Pop_and_Tech_Ratio), Population_B2)
```

```
Warfare_Deaths_B2_from_C_Adj =
MIN(ROUND(Population_B2*Warfare_C_and_B2_Adj_B2 * C_B2_Pop_and_Tech_Ratio),
Population_B2)

Warfare_Deaths_B2 =
IF (Circumscription_B2+Circumscription_C) >
(Circumscription_A2+Circumscription_B2)
THEN
Warfare_Deaths_B2_from_C + Warfare_Deaths_B2_from_A2_Adj
ELSE IF (Circumscription_B2+Circumscription_C) <
(Circumscription_A2+Circumscription_B2)
THEN
Warfare_Deaths_B2_from_A2 + Warfare_Deaths_B2_from_C_Adj
ELSE
Warfare_Deaths_B2_from_A2+Warfare_Deaths_B2_from_C

Warfare_Deaths_C_from_B1 = MIN(ROUND(Population_C * Warfare_C_and_B1 *
B1_C_Pop_and_Tech_Ratio), Population_C)

Warfare_Deaths_C_from_B1_Adj = MIN(ROUND(Population_C *
Warfare_C_and_B1_Adj_C * B1_C_Pop_and_Tech_Ratio), Population_C)

Warfare_Deaths_C_from_B2 = MIN(ROUND(Population_C * Warfare_C_and_B2 *
B2_C_Pop_and_Tech_Ratio), Population_C)

Warfare_Deaths_C_from_B2_Adj = MIN(ROUND(Population_C *
Warfare_C_and_B2_Adj_C * B2_C_Pop_and_Tech_Ratio), Population_C)

Warfare_Deaths_C =
IF (Circumscription_B1+Circumscription_C) >
(Circumscription_C+Circumscription_B2)
THEN
Warfare_Deaths_C_from_B1 + Warfare_Deaths_C_from_B2_Adj
ELSE IF (Circumscription_B1+Circumscription_C) <
(Circumscription_C+Circumscription_B2)
THEN
Warfare_Deaths_C_from_B2 + Warfare_Deaths_C_from_B1_Adj
ELSE
Warfare_Deaths_C_from_B1+Warfare_Deaths_C_from_B2
```