

Next Generation Simulations...

Require methods of representing: -

- Non Linear Battlespace.
- Complex Urban Environments.
- Cyber and CEMA effects.
- Impact of the 'Human Terrain' on military operations.

Applied to: -

- Command and Control Exercises.
- Operational Analysis.
- Data Visualisation.



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CONTEXT :

Researching supplements existing Kinetic tools.

The key requirements are

- Remove concepts like FEBA, and terrain 'ownership' (no hexes)
- Better representation of Urban
- Include Cyber and EM effects.
- The impact of the local population on military forces.

Existing tools struggle to replicate the interactions of Military Forces, Non State Actors and Civil Populations.

Our primary use case is C2 exercises and OA support on training events.

Higher tactical focus – Bn to Bde level formations.

Communication of the results is seen as a major issue

Human Terrain Aspirations

A Human Terrain model for Training and Analysis

- Work with real world and fictional settings and scenarios.
- Comprehensible output for both Analyst and Training Audience.
- Limited feedback loops.
- Link to other models (Kinetic, Cyber, Economic).
- Reacts to: -
 - Information Operations
 - Kinetic Events
 - Cyber Effects
 - Environment (CNI) Disruption
- Low cost of tools and supporting data.



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What do we need...

Handle legacy fictional scenarios like Arcadia and NATO DATE

Comprehensible :

The output of the model must not need extensive interpretation

Avoid complex feedback loops and chaotic behaviour, even when this is seen in the real world.

Poor training output

Since one model can not do everything, it must link to other models including kinetic warfare simulations.

React to a range of stimuli

Cheap, not just in terms of the actual tool, but also data acquisition and setup time.

Influence and Infrastructure Combat Model (IICM)

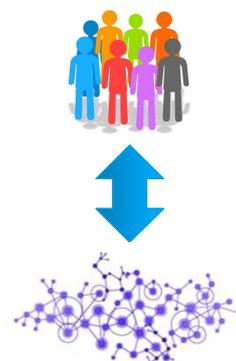
A Hybrid Warfare model that links infrastructure networks and the behaviour of dependent human populations.

- Explore the impact of Influence Operations and Cyber.
- Enables identification and analysis of 1st, 2nd and 3rd order impacts of attacks and disruption across a human terrain.
- Link to cyclical (time dependent) models.
- Indicative, not Predictive.

UK DSTL DASA program funded first of three expected project phases.

“To explore the effects of cyber and other hybrid operations on a civil population”

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IICM is a Concept Capability Demonstrator with a heavy bias on Cyber and Influence operations.

Originated in work on defensive cyber which required a human terrain model to evaluate collateral damage.

Part funded by DSTL via DASA open call.

The original objective was to link modelling of:

- CNI network interactions
- Human population

To enable identification and analysis of 1st, 2nd and 3rd order impacts of cyber attacks:

- 1st order – impact of disruption on an infrastructure network
- 2nd order – effects on the human population
- 3rd order – impact of the populations’ response on other networks

Kinetic (Cyclical Model).

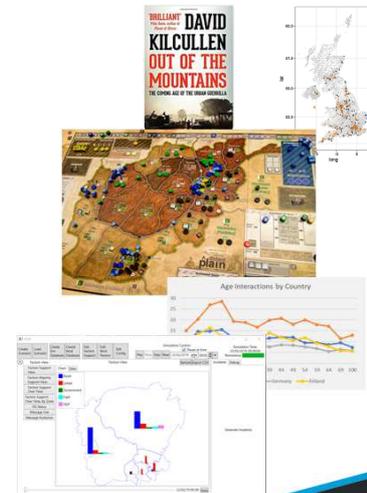
To understand the potential consequences of a hybrid and cyber operation.

Intended for training and education purposes. It will generate a credible response, not the response.

Completed the first of 3 expected phases.

Project Methodology

- Review academic studies: -
 - Social Interaction models
 - Counter-Insurgency and Influence operations
 - Urban Modelling
 - Infectious Disease models
- Investigate COTS gaming solutions.
- Identify open source datasets.
- Design a notional model.
- Construct software application to demonstrate technical viability.
- Test model on a UK teaching exercise to evaluate output.



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So how did we go about this...

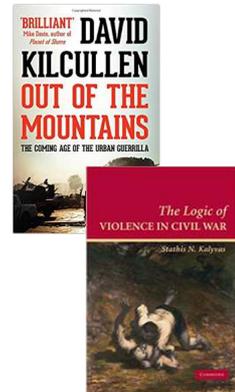
Lots of recent academic work looking at contemporary military operations
Looked at COTS games. Lots of recent developments

Open Source Datasets to avoid Social Media derived data.
Complex T&C's, plus ethical concerns.

Primary output of this project is a design, but needed to build a real system to identify design flaws....

Urban Areas and Cities

- Conflict takes place where the people are.
- Cities are: -
 - Densely populated
 - Rapidly evolving
 - Highly networked
- Cities **influence** surrounding areas. Destination for transport systems and trade.
- Cities contain **transient** populations with strong social connections back to their former communities.
- Cities are **contested** areas with competition between different communities and groups.



Ref : David Kilcullen "Out of the Mountains" 2015

S. N. Kalyvas "Logic of Violence" 2006

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How to represent 'geography'. Need to represent where people are in the landscape. Urban areas are crucial.

"Out of the Mountains" by David Kilcullen is a book looking at urban insurgencies.

First, conflict takes place where the people are, and increasingly people are living in dense urban environments and cities.

- These are expanding rapidly as populations move from the countryside into cities.
- Cities and urban areas are not like traditional terrains, as well as highly populated, they are constantly changing
- Highly interconnected and networked.

Cities act as a nexus for trade and transport systems and so create a powerful influence on the surrounding areas.

Throughout history, most cities rely on inward migration to sustain or grow their populations.

In the modern world, these immigrants maintain strong connections to the groups back home, often in the surrounding rural areas.

Cities are contested areas with competition between these different groups, very few

are homogenous.

The key point is that cities and dense urban areas are a special case within a population model and comprise the key nodes that show the greatest effect to disruption, be it physical, social or cyber in nature. So don't just model a population by social group i.e. tribe or political affiliation, we also need to model where they are in the landscape.

Contemporary Manual Wargames

COIN Series of Wargames published by GMT.
Focused on Counter Insurgency Operations throughout history.

Key design concepts

- Terrain is split into provinces or political blocks, not hexes or other regular shapes.
- Conflict is resource, not firepower, limited, so sustainability is a significant factor.
- More than two protagonists drive complex narratives.
- Forces are always visible, but they can only be attacked once they are geolocated.



*A Distant Plain (2013) – Afghanistan 2003-2013
Fire In the Lake (2014) - Vietnam 1964-1975
Colonial Twilight (2017) - Algeria 1954-1962
Pendragon (2017) - Britain 400-500 AD*

*Labyrinth (2010) - The War On Terror 2001-2010.
The Awakening (2016) - The War On Terror 2010-2016.*

Next War : Poland (2017)

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Play tested COIN and other current COTS wargames.

Colonial Twilight (2017) - Algeria 1954-1962 a main source...

These give us confidence that the complexity requirements can be met by a non kinetic wargame.

A couple of key points we learned from using these.

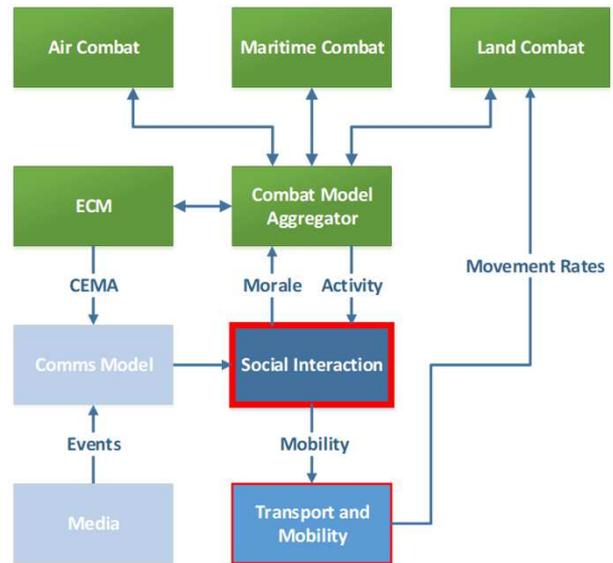
- A complex scenario only requires 10 – 20 geographical 'areas' to challenge the most advanced human player and give credible results.
- EN Forces are always visible. You know the enemy is in an area but you can not attack them until they make an overt move.
- Battles are won based on resources and logistics
- More than two active factions help drive the story forwards.

A different world view to a traditional combat model.

In effect we are looking at a computer model equivalent, working at the higher tactical level.

Key Model Features

- Military activity affects the population. *“Combat Model Aggregator”*.
- Cyber and CNI disruption change electronic communications. *“Capacity based Comms model”*.
- People move over a daily cycle between different geographic areas. *“Arc-Node based Transport and Mobility model”*.
- Messages most effective when passed face-to-face. *“Agent based Social Interaction model”*.



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This Phase concentrated on the Social Interaction model, an area we felt was least developed...

Early in the project we identified 4 key factors, each of which resulted in a sub model.

The Combat Model Aggregator is used to translate information in and out of the existing Kinetic warfare model.

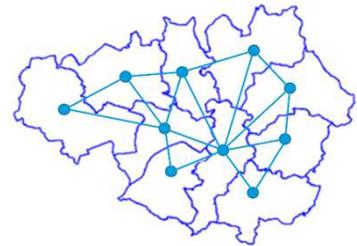
Must allow influence operations to target military units...

Comms model was deferred to a later stage, as was the detailed CNI models. Lots of COTS solutions.

Social Model - Geography

Geographical building block of a scenario

- Map divided into areas based on administrative regions (allows use of Census data).
- Rural and Urban areas are separated. Use 'Urban Terrain Zone' (UTZ) classifications.
- Local road networks form underlying Arc-Node based transport network between adjacent Zones.
- 'Control' of region may be contested by multiple groups.
- 10-20 Zones for a training model, more for an analytical model



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From the COIN type games we decided to work with a small number of 'Zones'
Easy to build from Census data. Practical to hand generate for legacy scenarios.

Edges often defined by geographical barriers that limit zone to zone mobility. See in
Admin region data...

-> rivers were often highways

Social Model - Factions

Most competition is conducted by non-state actors (Factions).

Different Factions have different objectives: -

- Government = Preserve stability, maintain powerbase.
- Insurgents = Change the political system
- Security Agency = Information gathering and peace enforcement.
- Hactivists = Change governmental policy / accumulate social capital.
- NGO / NSA = Raise publicity for a cause, protect reputation.
- Industry = Encourage trade.
- Militia = Community defence.
- Criminal = Make money.
- Military Forces = Gain a tactical advantage.

Dynamic and dramatic tension between factions...

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The main problem is how to split a population into groups.
Political building block of a scenario

Whilst many military exercises only have two or three sides, a hybrid model is much more complex.

It should contain lots of active factions each with their own agenda, and, if played, their own 'win' conditions. Key driver of asymmetry

These factions exhibit shifting alliances, the effects of which are critical to the human terrain model.

Decisions made by the training audience might favour one faction over another and so change their allegiances.

The military forces may not be a dominant faction, but they should be represented in the population model (so they can be attacked by Influence operations).

Social Model - Group Dynamics

People belong to multiple groups: -

Group	Examples	Duration	Orientation	Model
Primary	Family, Close Friends, Gangs	Long	Relationship	Home Zone
Social	Co-Workers, Sports Teams	Medium	Task	Work Zone
Categories	Political, Religion	Medium	Self Identified	Faction
Collective	Flash Crowd, Audience	Short	Spontaneous	Emergent

Key to modelling *'Influence Operations'*

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When we look at how people fit into these factions we can use a set of concepts derived from Group Theory.

These are critical to modelling Influence operations

People belong to groups. Collective behaviour is not an aggregation of individual behaviour, in many cases, much easier to model.

However, the model needs to encompass multiple types of group interactions...

Primary group can be captured by geography – closely linked to where you live. -> Night-time location

Social group -> optional day-time location

Categories -> Faction. Static over a period of weeks to months.

Collective – An output of the system (i.e. a riot or demonstration), not stored between cycles.

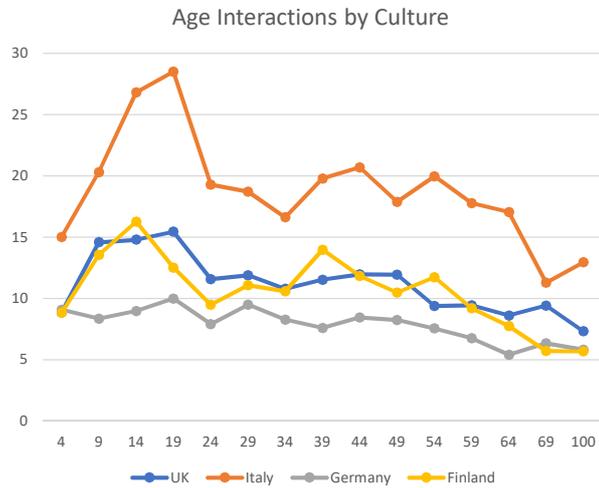
Social Model – Age and Culture

Germany							
Age	00-09	10-19	20-29	30-49	50-64	65+	SUM
00-09	2.66	0.33	0.28	1.01	0.41	0.24	4.92
10-19	0.90	4.70	0.73	2.38	0.47	0.58	9.75
20-29	0.93	1.08	3.48	1.96	1.18	0.44	9.05
30-45	1.57	1.16	1.28	3.98	1.59	0.93	10.50
45-64	0.60	0.65	0.96	2.01	2.22	0.87	7.31
65+	0.69	0.36	0.39	0.97	1.00	1.71	5.11
SUM	7.34	8.27	7.11	12.29	6.86	4.76	46.63

UK							
Age	00-09	10-19	20-29	30-49	50-64	65+	SUM
00-09	5.08	1.24	1.28	2.68	0.89	0.54	11.70
10-19	1.23	8.06	1.45	2.96	1.12	0.93	15.73
20-29	1.10	1.17	3.60	3.15	2.22	0.89	12.12
30-45	1.86	1.85	1.80	4.87	2.44	1.22	14.04
45-64	0.64	0.79	1.16	2.88	2.27	1.22	8.97
65+	0.25	0.32	0.41	1.28	1.31	1.76	5.31
SUM	10.16	13.41	9.69	17.81	10.25	6.55	67.86

Italy							
Age	00-09	10-19	20-29	30-49	50-64	65+	SUM
00-09	8.30	0.90	0.56	3.66	1.75	0.57	15.73
10-19	1.33	17.97	1.34	3.57	4.79	1.36	30.36
20-29	0.88	1.79	7.44	4.41	2.88	1.15	18.53
30-45	2.43	1.88	3.15	9.20	4.21	1.89	22.75
45-64	1.10	1.72	2.01	4.67	4.23	1.83	15.55
65+	1.32	0.76	0.93	2.73	3.22	2.57	11.52
SUM	15.35	25.01	15.42	28.23	21.07	9.36	114.43

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Decided early on to focus on face to face interactions.

A rich data source was found when looking at infection modelling.

POLYMOD is an example of the kind of data available...

Well understood branch of Math dealing with this data.

Major cultural differences seen in data. Some populations are more gregarious than others.

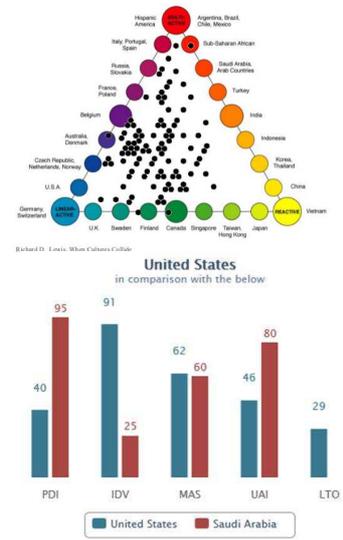
Each faction can have an assigned cultural age interaction table.

Social Model - Cultural Distance

Measures the ability of groups to communicate with each other. Two models depending on the training audience: -

- Lewis 3 way model.
 - Simple data setup.
 - Easy to explain to training audience.
 - Pre-generated into a single 'chance of successful communication' factor between each Faction pair.

- Hofstede Cultural Dimensions model (6 way).
 - Higher fidelity.
 - Allows each message to include cultural targeting factors
 - Avoids requirement for multiple messages to describe each event.



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Chance of successful communication between two groups. Placeholder models selected for development.

Replace later once problem better understood

Lewis type model allows us to generate a single number to describe the distance between any two factions.

- Simple, easy to explain to a TA.
- Plenty of source data
- Good for Face-to-Face communications

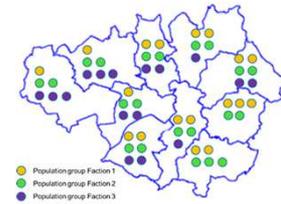
More complex models exist. For instance, Hofstede type model requires evaluation against each axis.

- Allows multi-modal messages
- May be more complex than required for a general TA but good for info ops specialists (77X etc)...

Social Model - Population Group

Social building block of a scenario

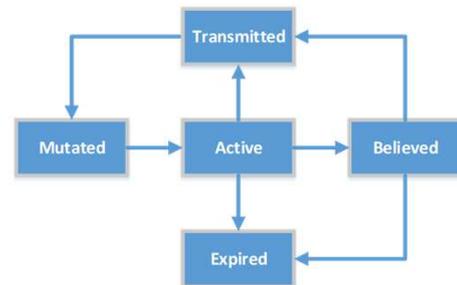
- Sub group of a population within a region.
- Shared faction, movement characteristics and age band.
- Have a daily activity cycle based on social interaction studies.
- Modelled by a Semi-Autonomous Software Agent.
- 10's to 100's of PGs per region.
- Optional non geographic groups to represent Diaspora.



Message Model

Messages are memes: -

- Encode change in support for a faction (sentiment).
- Modelled as software agents that replicate through a human terrain.
- 'Cultural Distance' limits message transmission and comprehension.
- Messages distort and evolve as they are transmitted.
- 10's of messages per PG, 1000's of unique messages in a running scenario.



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Message model governs the passage of information between population groups

SMCR based model. Stressed a single Channel in this iteration

Hour based clock ticks allows us to synchronise with the kinetic model

Age and location data tells us who could interact at a given point in time

Social Media modelled by averaging the influence over an entire faction and applying a bias to all members.

Information will find a way, be it telephone, email or Facebook.

Population Group Behaviour

- A PG measures support for all factions, including its own. Messages change these values.
- PGs travel between regions but have a default Home and Work region where most interactions take place.
- A PG holds a list of active 'messages' that are exchanged when they interact with each other.
- Social Media effects applied by an hourly 'smoothing model'.

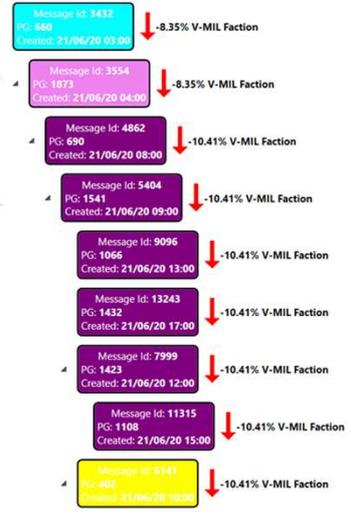
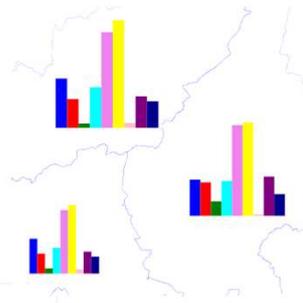
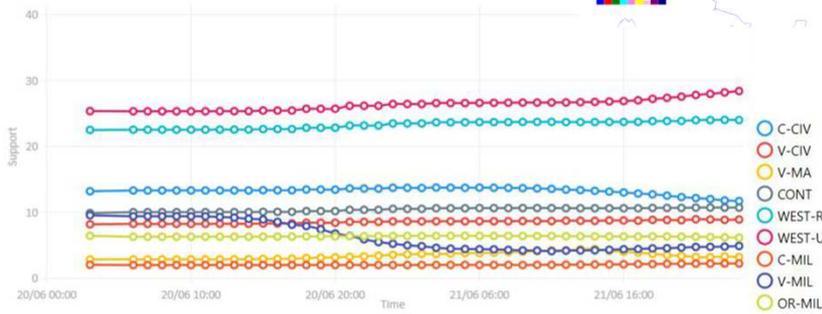
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Measuring sentiment – or how each faction is perceived by the others.
Travel links back to the infrastructure networks, the original project aim!
Messages currently exchanged face to face on an hourly basis – big effects
Smoothing model only adjusts sentiment, no message replication. Diaspora effects...

Model Outputs

- Faction Support over time
 - Whole scenario
 - By geographical region
 - Message infection rates over time
 - Message evolution over time
- SQL Database to allow data mining...



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Model outputs levels of support by region, faction or individual Population group element

Can trace a specific message to see how it evolves.

See faction support change over time as messages flow through the systems. By entire model or within a region.

Next project stage to look at better outputs. Probably Power BI based.

Conclusions

- Demonstrated information flow through a Human Terrain.
- Model suitable for both manual and computer assisted wargames.
- Census and infection modelling data provides a useful base dataset that does not require Social Media derived databases.
- Computerised infection models provide a useful model of information flow in a population. Best suited for problems with
 - Regional focus (1000's to 1 million population), Town to UK County sized regions.
 - Interaction with external Geocentric models
 - Education and Training

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Project is still ongoing, but first phase has concluded. Results from current testing show that

The basic analysis provides useful results

PG group 50 -250 people, so 500-1000 PG entities
Links into Map based models (i.e. Kinetic wargames)

QUESTIONS?

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Hopefully a good overview....

SPARE SLIDES

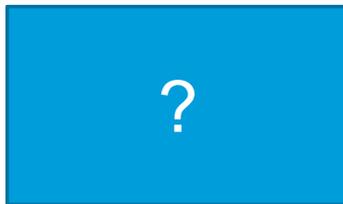
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The Tactical 'Hybrid' gap

Military or Civil

- Staff – General awareness training (Cyber, Personal Security)...
- Systems Operators – How to operate specialist equipment...
- **Tactical Commanders – Consequences of Hybrid operations...**
- Operational Commanders – Campaign Objectives, ROE
- Strategic Commanders – Define Doctrine, Strategic Goals



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Hybrid is often seen as a strategic effect, but we wanted to explore the effect on the tactical command level.

Cyber as a primary effector. Not covered by 'normal' military training.

Pictures.

Left NORSE shows a typical network monitoring tool showing communication flows between systems. Real time but specialist... The kind of thing a cyber specialist might use to understand how an attack is progressing or monitoring systems on a minute by minute basis.

Right shows the new Russian Command and Control room. Here they are concerned with the multi-domain battle, looking forward days to weeks. Can be handled by traditional exercises.

We are interested in what sits in between, which is the Tactical commander level.

Can be subject to hybrid attack, may order cyber or hybrid effects.

Unlike to initiate or respond personally, they are commanding teams of specialists, Not setting long term policy or RoE, that comes from above, but is required to influence local events..

Thinking and planning for Hours to Days

Transport Modes

- Public data did not support original assumptions that disruption to public transport would change population flows.
- Public transport not a significant factor for test area (Southampton).
 - Car transport over 85% of region-region transport.
 - Non car transport only critical for areas like Inner London (84%).
- Difficulty in obtaining age distribution data to match transport model.

Region of residence	Car	Motorbike	Bicycle	Bus/coach	Rail	Walk	Other
London	29	1	6	15	38	10	1
Inner London	14	2	10	17	42	13	2
Outer London	39	1	3	13	36	8	1
South East	71	1	4	4	10	10	1
South West	74	1	5	5	2	14	1
East of England	70	1	4	3	11	10	1

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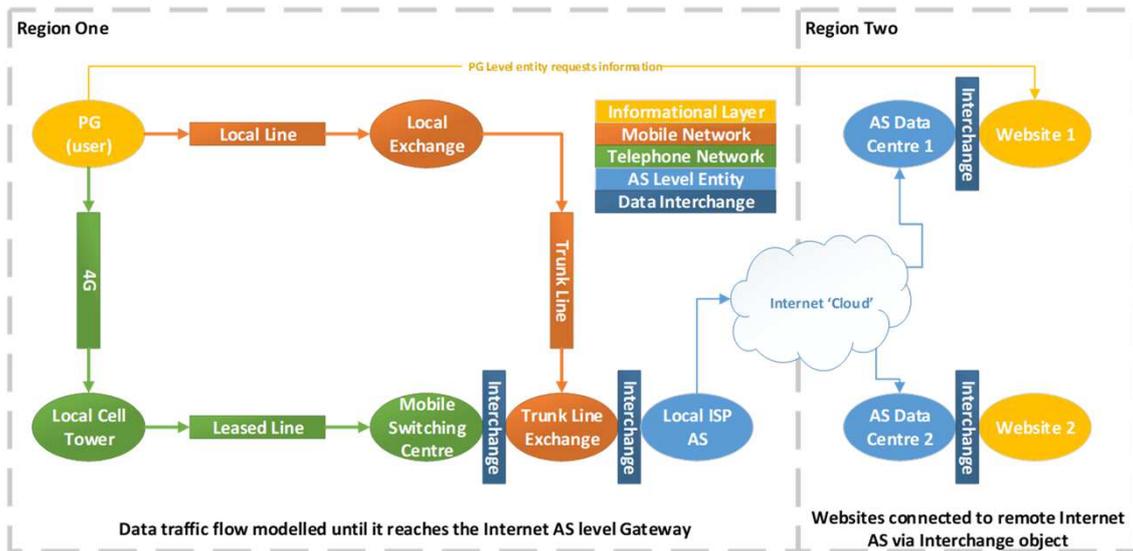
We expected to see a major impact from transport disruption.

Manual playtesting and spreadsheet analysis do not back this up for datasets other than central London (where it is the dominant factor).

Link back to DK work on how megacities diverge from 'urban' areas

Further research needed (moved to bottom of the pile for now)

Modelling the Internet



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One area that raised a lot of questions was the appropriate level to model the internet.

Internet consists of a large number 50,000 or more Autonomous Systems (clusters of computers)

Connected via Border Gateway Protocol.

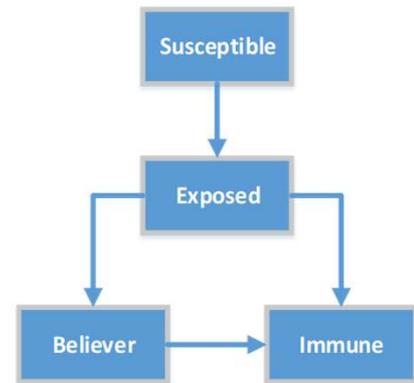
Since there are many redundant connections, decided to model the local connection to the cloud, not the transmission of information within the cloud.

A user has one or more methods of connecting to 'the internet'.

Compartment Models

A set of models used to simulate the spread of infectious diseases.

- SEIR (Susceptible, Exposed, Infected, Recovered) type population states.
- Chance of interaction is population age dependent.
- 'CD' between source and potential host used to test for chance of infection (Successful communication).
- Intense messages are more virulent.
- A message can be passed on even if the host does not 'believe' it.



Message Model - 1

IICM models the effects of discrete messages on population groups as changes in support for factions.

- Implements a modified Sender-Message-Channel-Receiver (SMCR) communication model.



- Splits a message into a delivery mechanism and payload.
- Payload is a 'Meme' which conveys influence.
- Core model uses Hour long activity ticks.
- 'Smoothing Model' for social media effects.

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Message model governs the passage of information between population groups

SMCR based model. Stressed a single Channel in this iteration

Hour based clock ticks allows us to synchronise with the kinetic model

Age and location data tells us who could interact at a given point in time

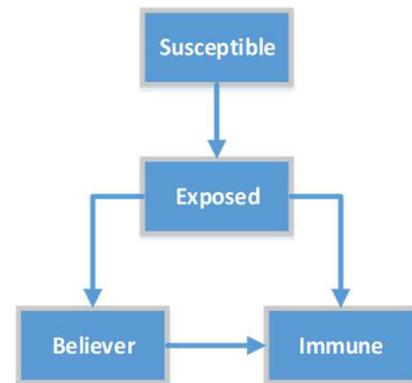
Social Media modelled by averaging the influence over an entire faction and applying a bias to all members.

Information will find a way, be it telephone, email or Facebook.

Message Model - 2

Messages transmitted between co-located population groups using an infection-like (SEIR) modelling algorithm.

- Chance of interaction is population age dependent.
- 'CD' between source and potential host used to test for chance of infection (Successful communication).
- Intense messages are more virulent.
- A message can be passed on even if the host does not 'believe' it.



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Compartment models are common in infection modelling.

We have adapted a standard SEIR to only allow infection with a specific message once.
No Recovery phase

Split a population into groups. We have used this at two levels,

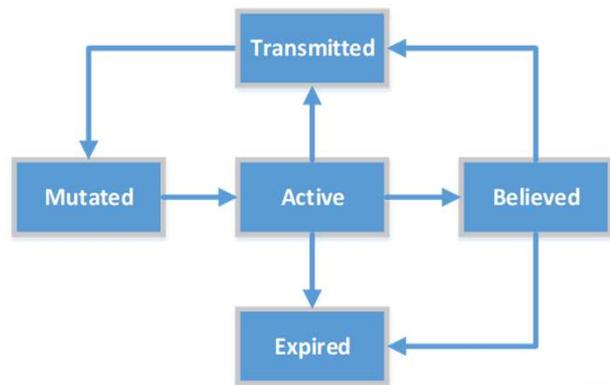
- Agent based model for interactions between population groups.
- A true compartment model within a Population Groups (required when groups are more than 100 people in size)

A message is most likely to be believed if it comes from the same faction as the potential host.

Message Model - 3

Messages have a life cycle in the host:

- Messages have an originator faction.
- Messages age and 'Expire'.
- Expired messages are no longer infectious and give immunity.
- Active messages may be 'Believed' to deliver an influence change.
- Low CD value between originator and host = greater chance of belief.
- Messages may 'mutate' form as they are transmitted. High CD = greater chance of mutation.



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Active Message stack evaluated each clock tick and may be triggered to deliver the payload

Messages that give a strong influence change are more virulent (more interesting)

Expired messages are kept as they produce an immunity to the same message

Mutated messages may change virulent, lifespan or influence.

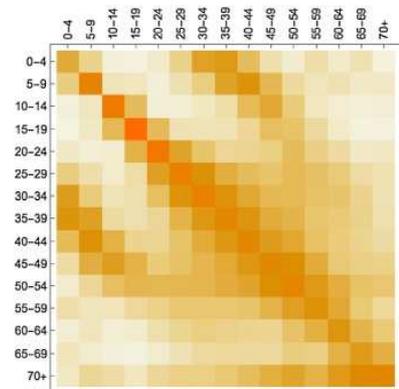
Population Age Communication Factors

Age of an individual affects the chance of social interaction (POLYMOD dataset).

- Defined a Population Group by: -
 - Home Location (Primary Group)
 - Work Location (Social Group)
 - Faction (Categories Group)
 - Age Band
- Constructed a related 24 hour activity cycle per age band.

Adding Age factor results in more PG entities and more complex data setup but much better information flow.

[Social Contacts and Mixing Patterns Relevant to the Spread of Infectious Diseases](#) : Mossong et al. 2008



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When breaking a population into groups, we need to consider age.

Note the strong intensities of interactions in the 10-19 year band.

A Population group is defined as a group of people who

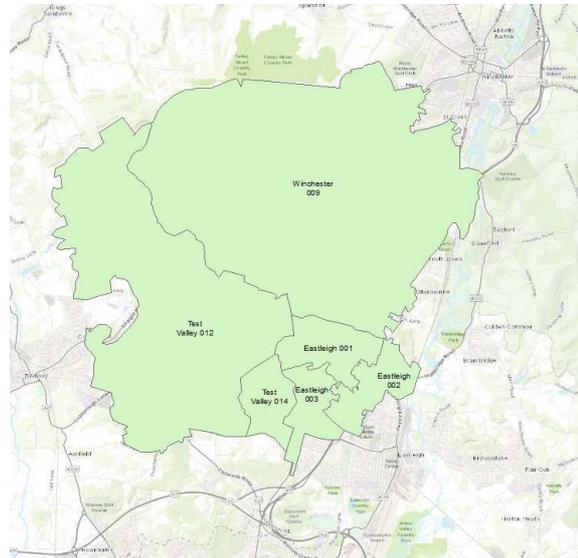
- Have a common Home and Work location (District or Zone)
- Belong to the same faction
- Common age band (4-6 different age bands in current testing)

Typically 100's to 1000's in a model.

Adding Age resolved some artefacts we saw in the test data on information flow in rural areas. Schools were the missing factor.

Sample - Chandlers Ford

- 6 Districts.
- 55K Population.
- Rural and Urban mixture.
- Road transport links.
- 5 Factions: -
 - Rural Civil.
 - Urban Civil.
 - Government.
 - Farm Workers Union Insurgents.
 - Military Forces.
- Tactical level exercise.

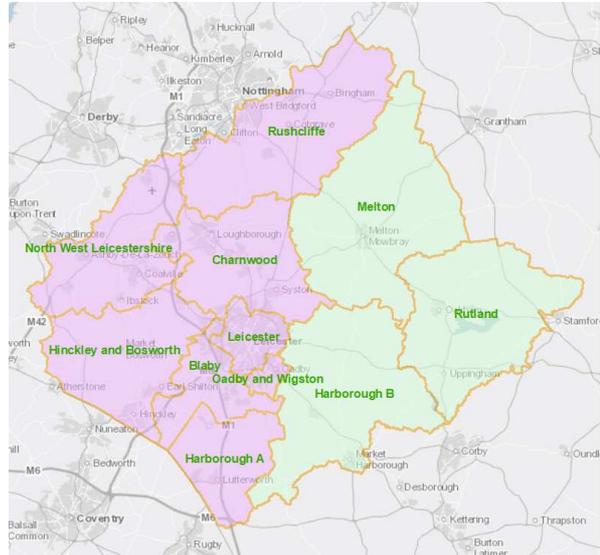


Representative of a small production model based on UK Census data

Good information flows to manual events

Sample – Adept Cormorant (ACSC)

- 11 Districts.
- 350K Population.
- Rural and Urban mixture.
- Road transport links.
- 9 Factions: -
 - CIN Civil Nationalists
 - VED Civil Nationalists
 - Local Militia
 - Continentals (Immigrant)
 - Westrian Rural (Local Ethnic)
 - Westrian Urban (Local Ethnic)
 - CIN Military
 - VED Military
 - ORL Military
- Operational level exercise.

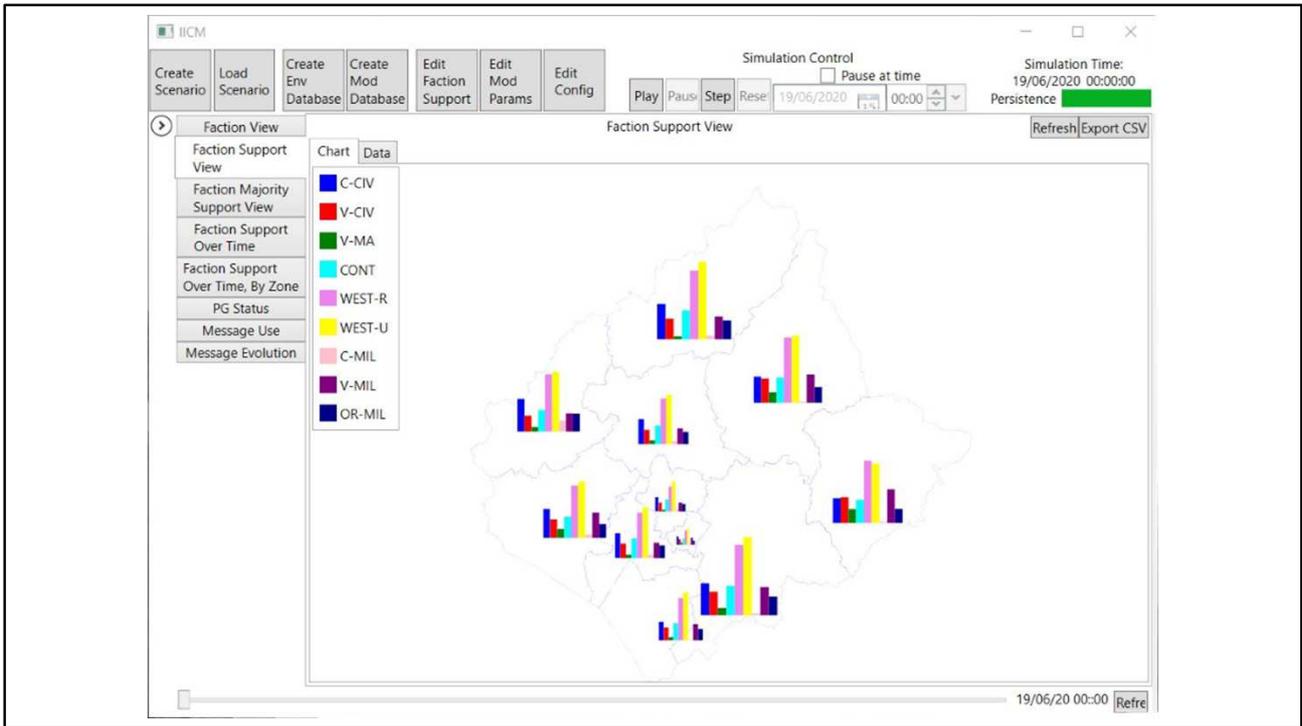


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Large production model based on UK Census data
Force Intervention exercise

Used on ACSC 2019 to test ORLAND influence operations

Complex factional balance for experienced audience

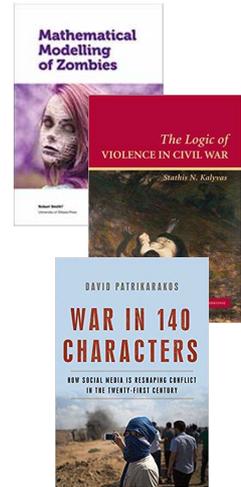


IICM Model output

ACSC 2019 Arcadia Scenario. Post CIN invasion.

Selected Biography

- Out of the Mountains: The Coming Age of the Urban Guerrilla by David Kilcullen (2015)
- The Logic of Violence in Civil War (Cambridge Studies in Comparative Politics) by Stathis N. Kalyvas (2006)
- Mathematical Modelling of Zombies by Robert Smith?
- War in 140 Characters: How Social Media Is Reshaping Conflict in the Twenty-First Century by David Patrikarakos (2018)
- BBC Four Pandemic Model 'Haslemere dataset' (2018).



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Key Texts