



CENSUS

THE SYSTEMIC BACKBONE of PLAY-AS-ANYONE in
WATCH DOGS: LEGION

GDC 2021

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PLAY-AS-ANYONE ALLOWS
PLAYERS TO RECRUIT ANY
CHARACTER IN THE WORLD

Census High Level Requirements

- / London is massive the population can't be preaked or scripted
- / Census needs to generate a wide variety of characters that are **consistent** with their role and appearance
- / Characters must be simulated **persistent** to provide opportunity for player interaction and recruitment
- / Census must respect strict performance budgets

Roadmap

Census



- Character Generation
- / Simulation Layer
- / Operation Management
- / Recruitment Layer
- / Wrap-up Example

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Roadmap

Census



- Character Generation*
- / Simulation Layer
- / Operation Management
- / Recruitment Layer
- / Wrap-up Example

*Credit: Farbod Teedaynoor, Game Systems Programmer

Character Profiles

/ Census Data

- / Gender
- / Age
- / Ethnicity
- / Fashion
- / Occupation
- / Income
- / Personality
- / Voice
- / Birthplace
- / ...and more!



Gender.Female

Ethnicity.Caucasian

AgeRange.Adult

Voice.PassionateActivist

Occupation.Paramedic

Income.Low

Personality.Heroic

Birthplace.Wales

Fashion.Casual

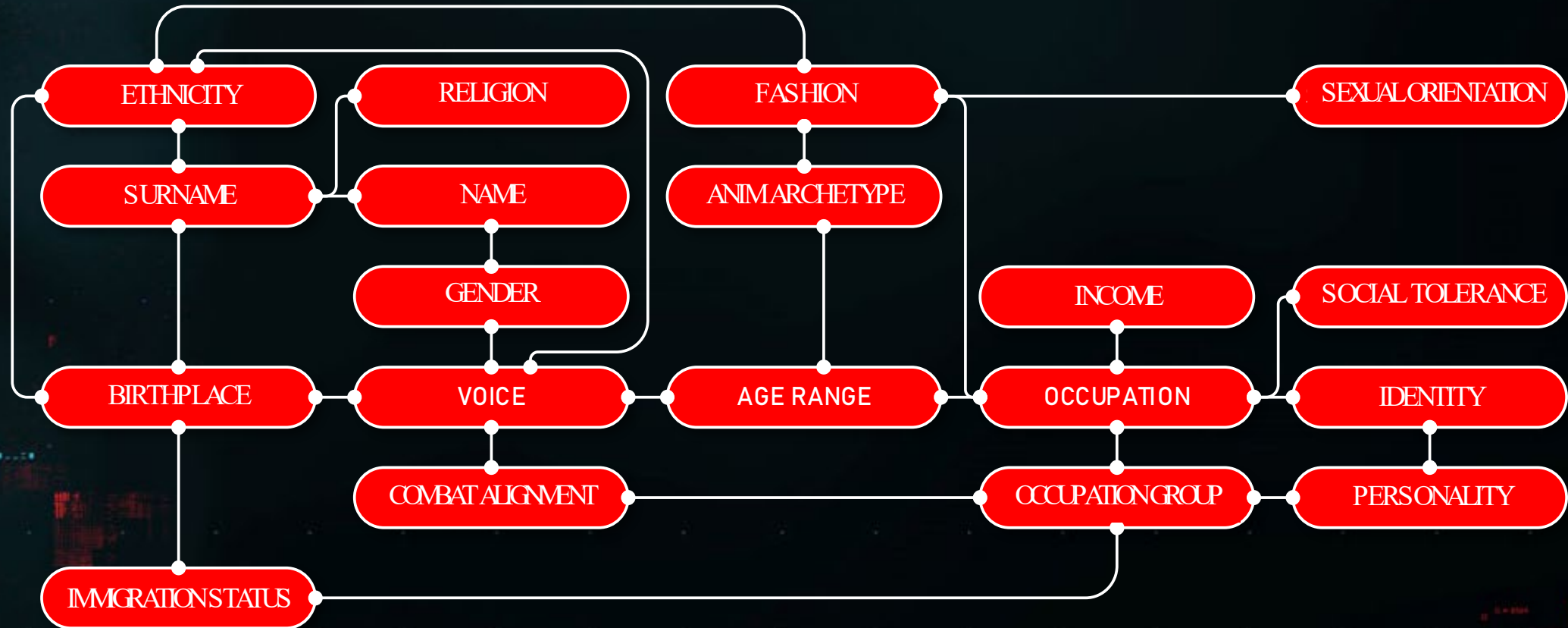
Anim.Trained

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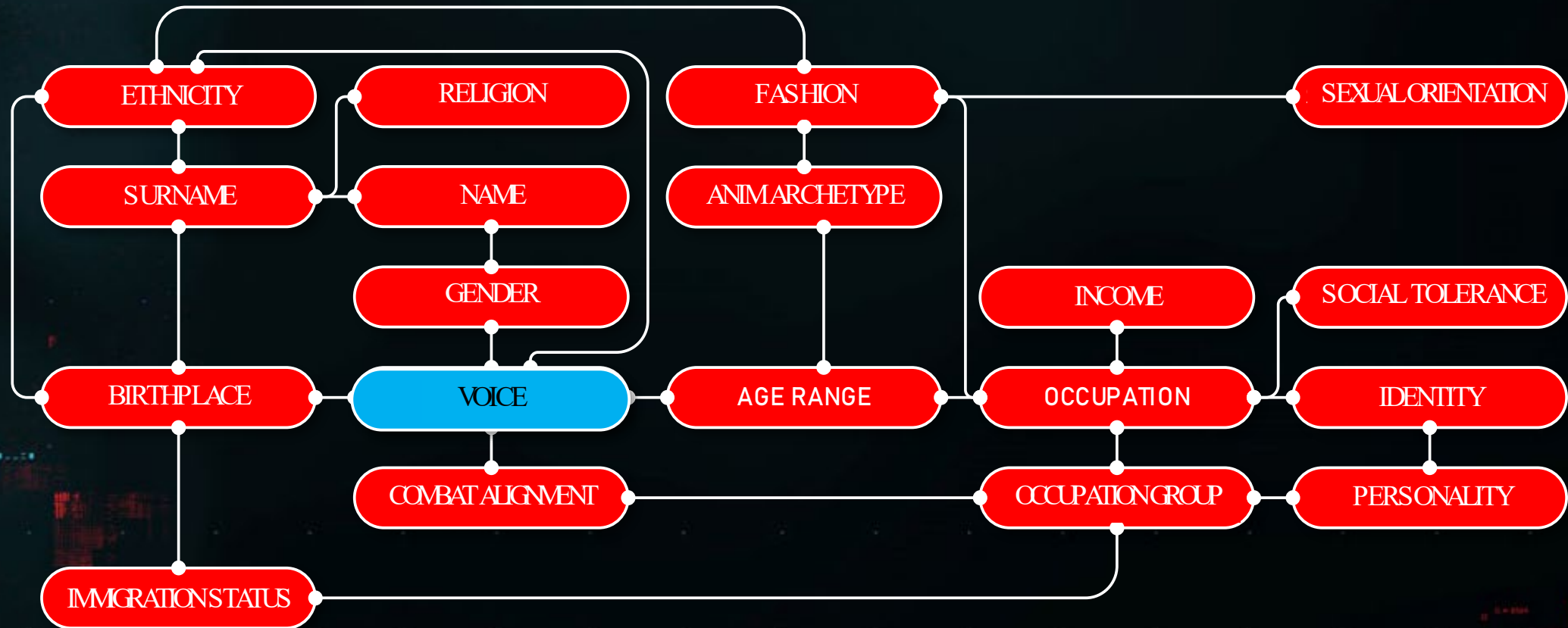
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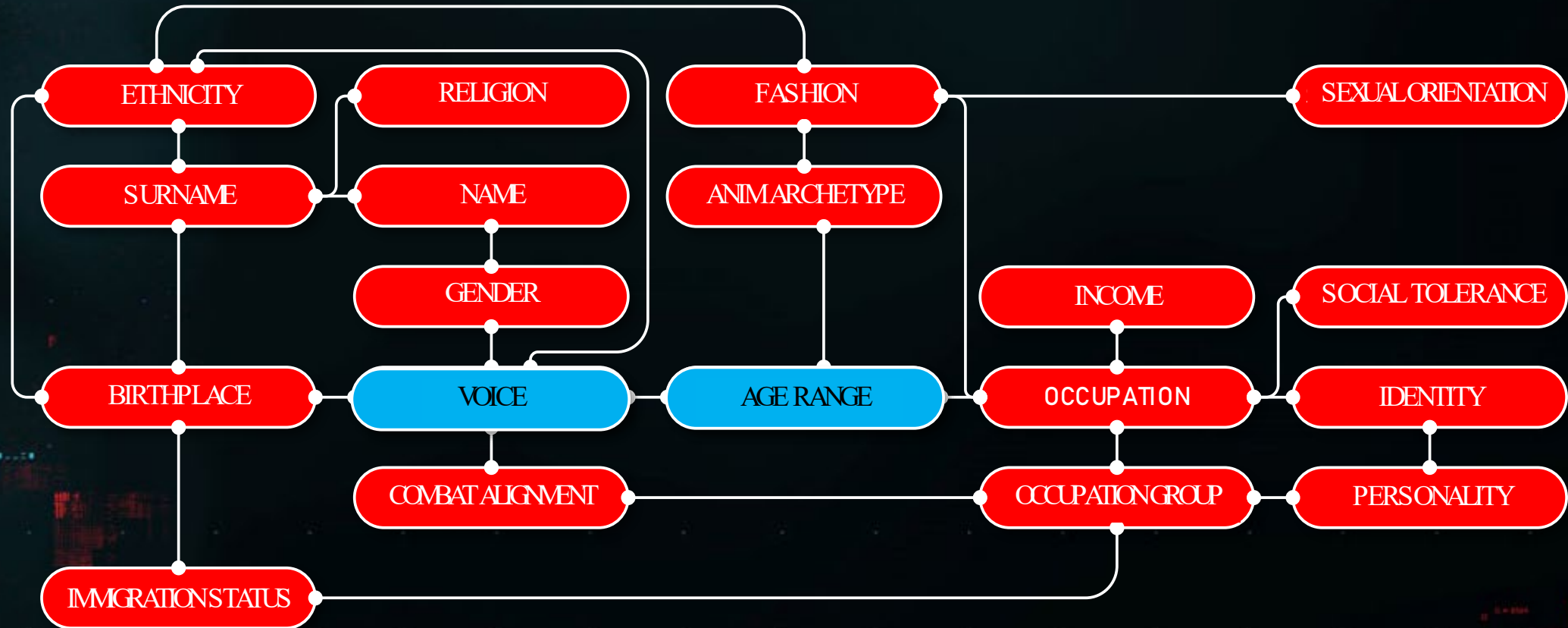
Character Profiles



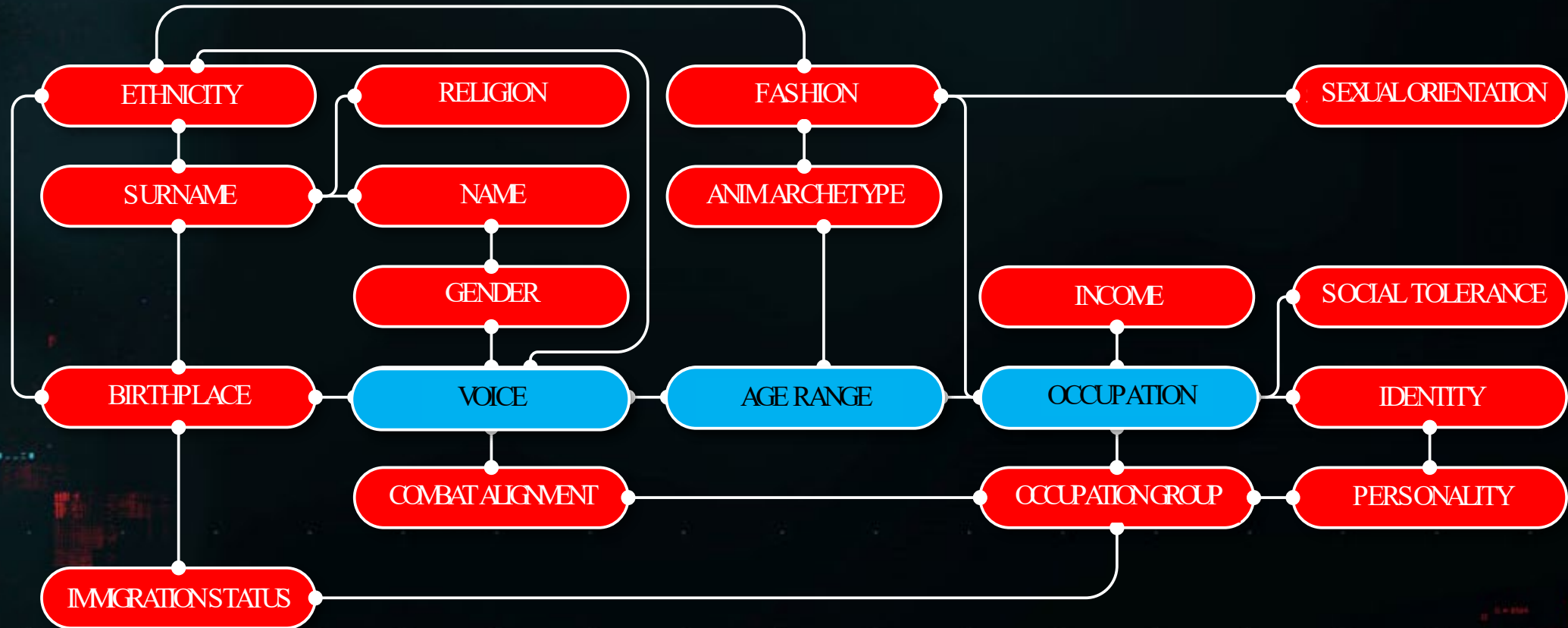
Character Profiles



Character Profiles



Character Profiles



Profile Refinement

/ Flood fill algorithm:

OCCUPATION
Aerospace Engineer
Albion Contractor
Anaesthesiologist
Animator

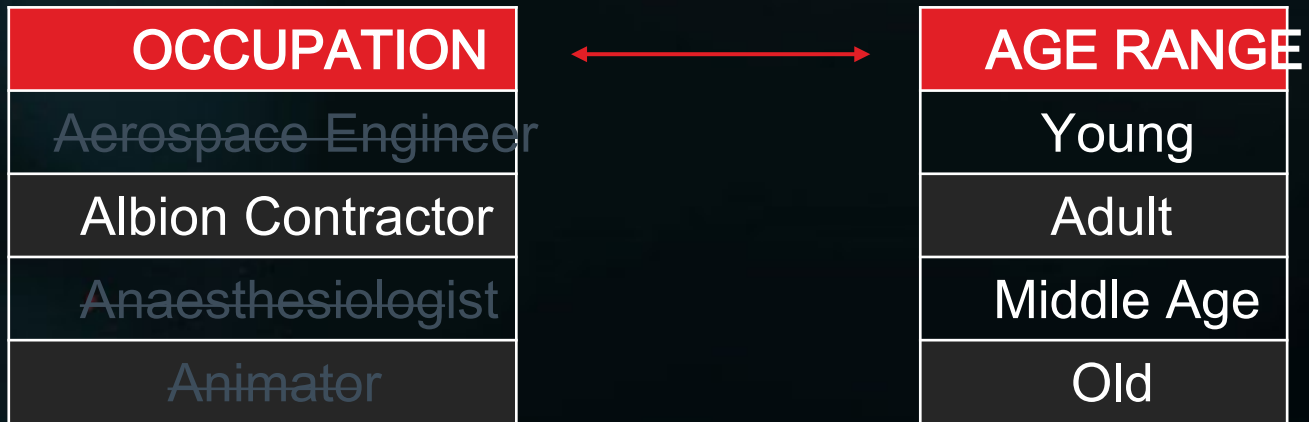
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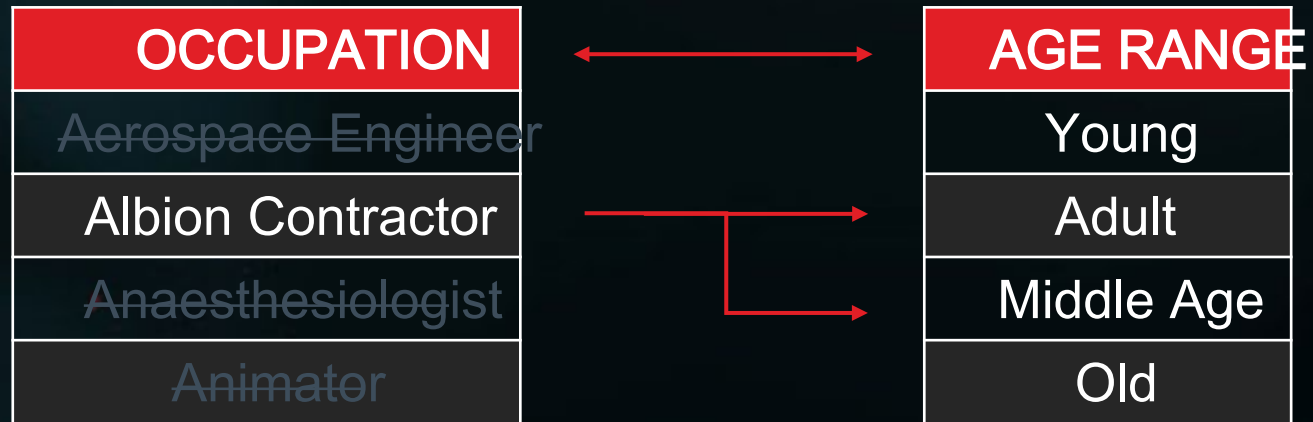
Profile Refinement

/ Flood fill algorithm:



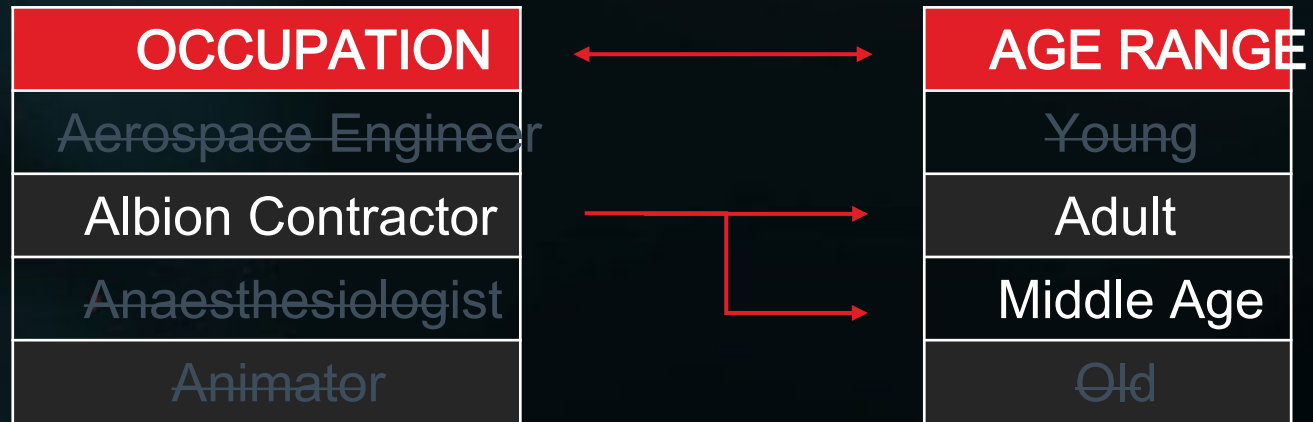
Profile Refinement

/ Flood fill algorithm:



Profile Refinement

/ Flood fill algorithm:



Profile Refinement

/ Flood fill algorithm:



/ **Anomaly** if any field has all values removed

/ Full refinement uses a fixed field ordering for debugging and calculation of conditional probabilities for design tuning

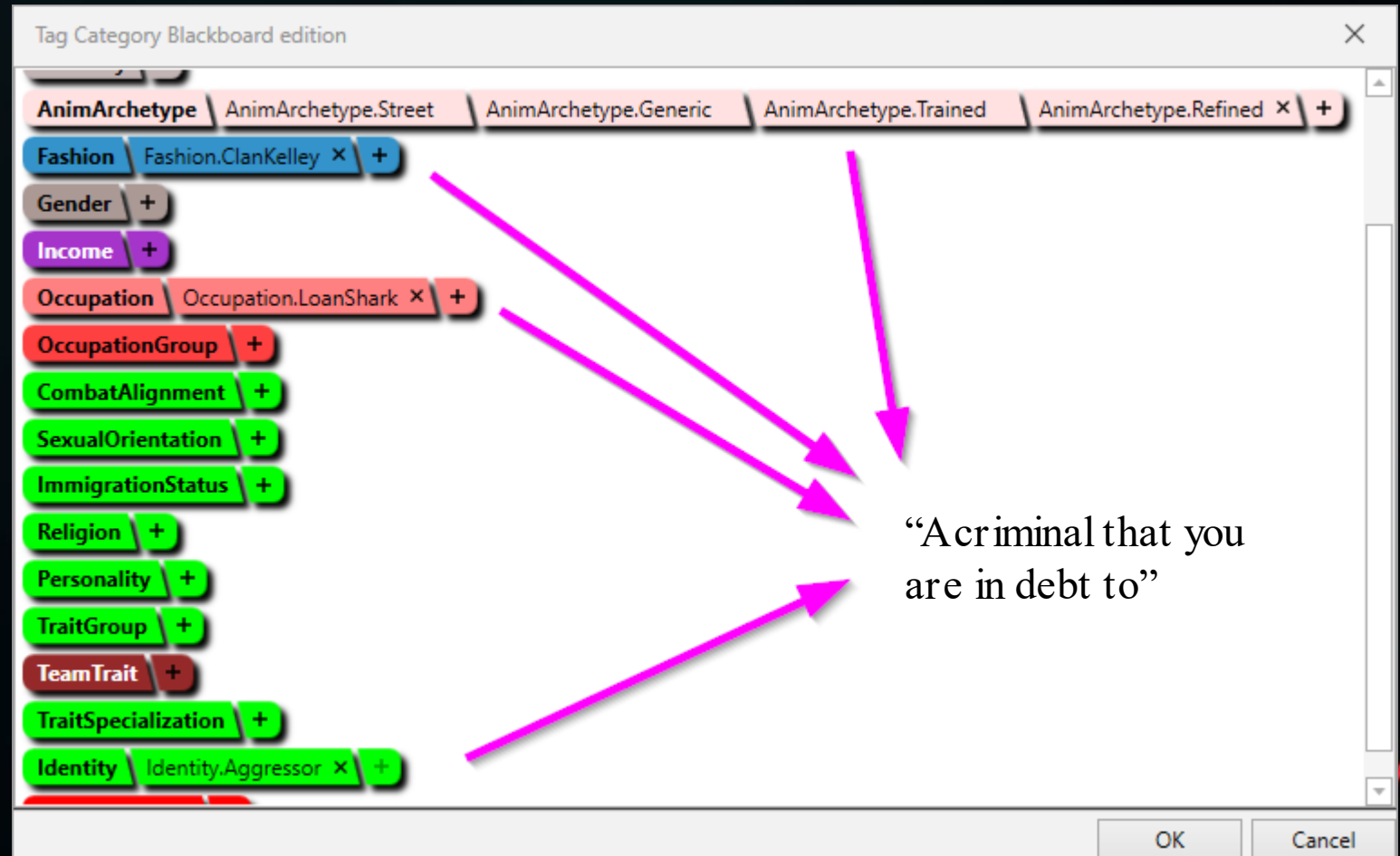
Census Field Relations

/ Example: Occupation is linked to age range and fashion type

Occupation	Age Range	Fashion	Bias	Distribution
Accountant	Adult	Business Casual	125	0.043%
Accountant	Young	Business Casual	125	0.043%
Accountant	Adult	Business Formal	125	0.043%
Accountant	Young	Business Formal	125	0.043%
Accountant	Middle Age	Business Formal	150	0.051%
Accountant	Old	Business Formal	100	0.034%
Accountant	Middle Age	Business Tradition	10	0.003%
Accountant	Old	Business Tradition	10	0.003%

Census Profile Filters

- / The outward facing view of a Census profile
- / Used to gate content or direct generation



Census Performance

- / Used SQLite on PS4 for prototyping, but performance was unacceptable
- / Engine team created a custom **bit-field representation**
 - / Each census field is represented in memory as a bit field
 - / Bit-fields are statically allocated during initialization to take advantage of cache locality, avoiding cache misses and expensive dynamic allocations

Census Relation Tables

Diagram illustrating the relationship between Occupation, Age Range, and Fashion categories:

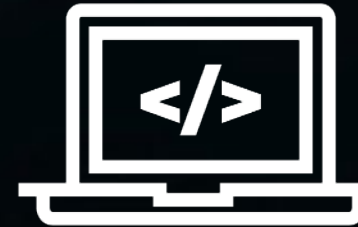
- Occupation: Accountant, Activist, Actor
- Age Range: Young, Adult, Middle Age, Old
- Fashion: Business Casual, Business Formal, Business Traditional, Cyberpunk, ...

		Business Casual	Business Formal	Business Traditional	Cyberpunk	...
Age Range	Young	1	1	0	0	
	Adult	1	1	0	0	
	Middle Age	0	1	1	0	
	Old	0	1	1	0	

Census Performance

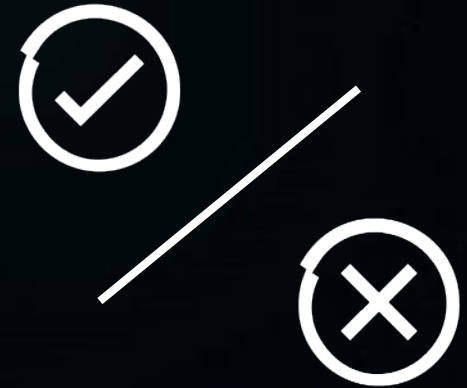
/ Shipped data:

- / 19 fields
- / Total of 919 values (not including names/surnames)
- / 18 825 relations
- / Full refinement takes 0.6s worst case



Character Profiles-What Worked and What Didn't

- / Trusting the system yielded good results
 - / There was a constant temptation to make 'perfect characters', but with focused tuning, the system could generate more interesting results
- / Performance was an ongoing concern
 - / New features required new fields and new relations causing unacceptable growth of the relation tables
- / Floodfill can pigeonhole refinement
 - / @Alpha "Why are 20% of people in the world footballers..."



Roadmap

Census



- Character Generation
- / Simulation Layer *
- / Operation Management
- / Recruitment Layer
- / Wrap-up Example

* Credit: Stuart Rudderham, Game Systems Programmer

Character Simulation

- / Primarily expressed through character **schedules**
 - / Gives backstory and purpose to characters in the game
 - / Enables persistence
- / Persistent characters facilitate repeated player interactions over time



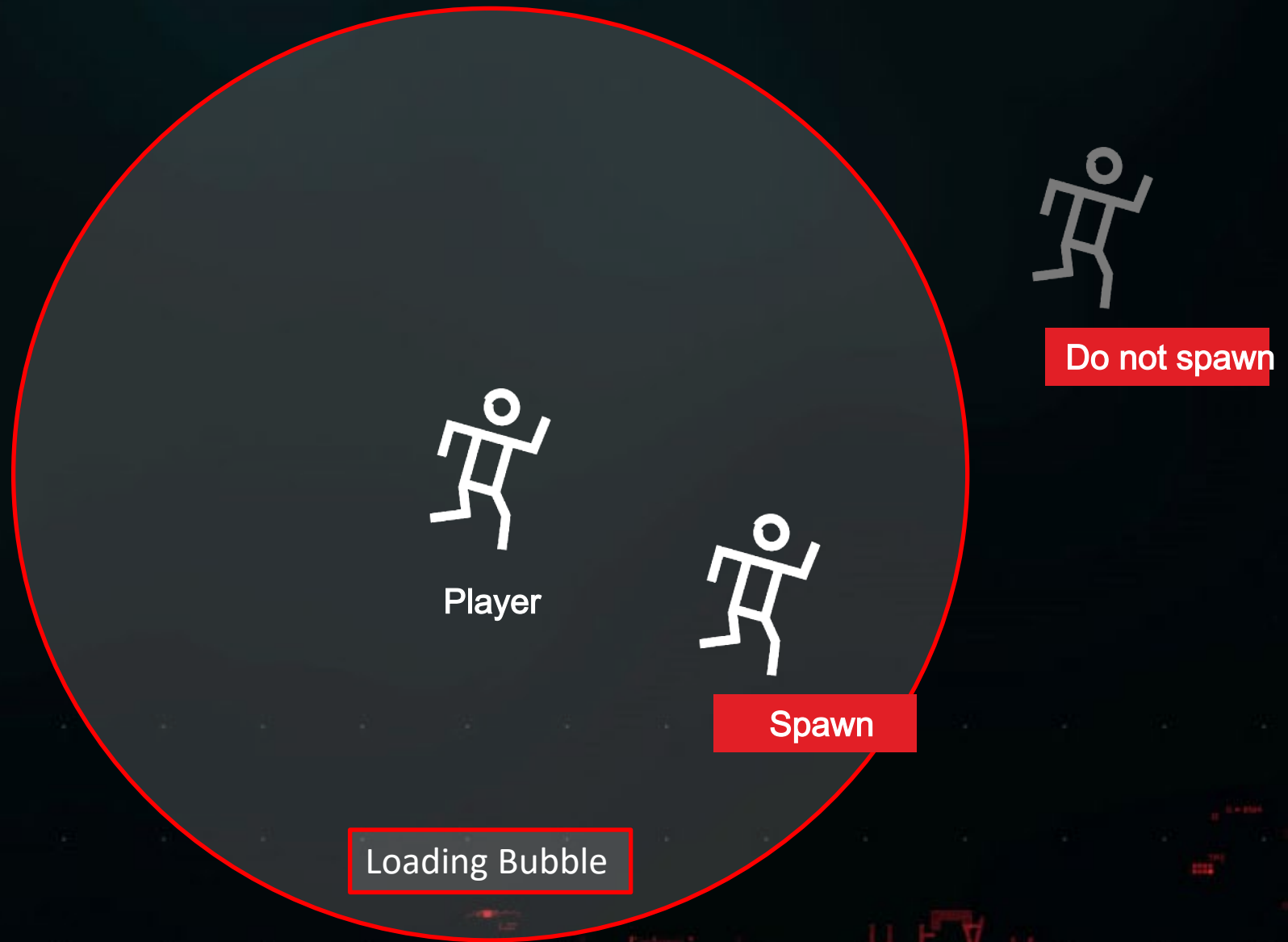


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Persistence



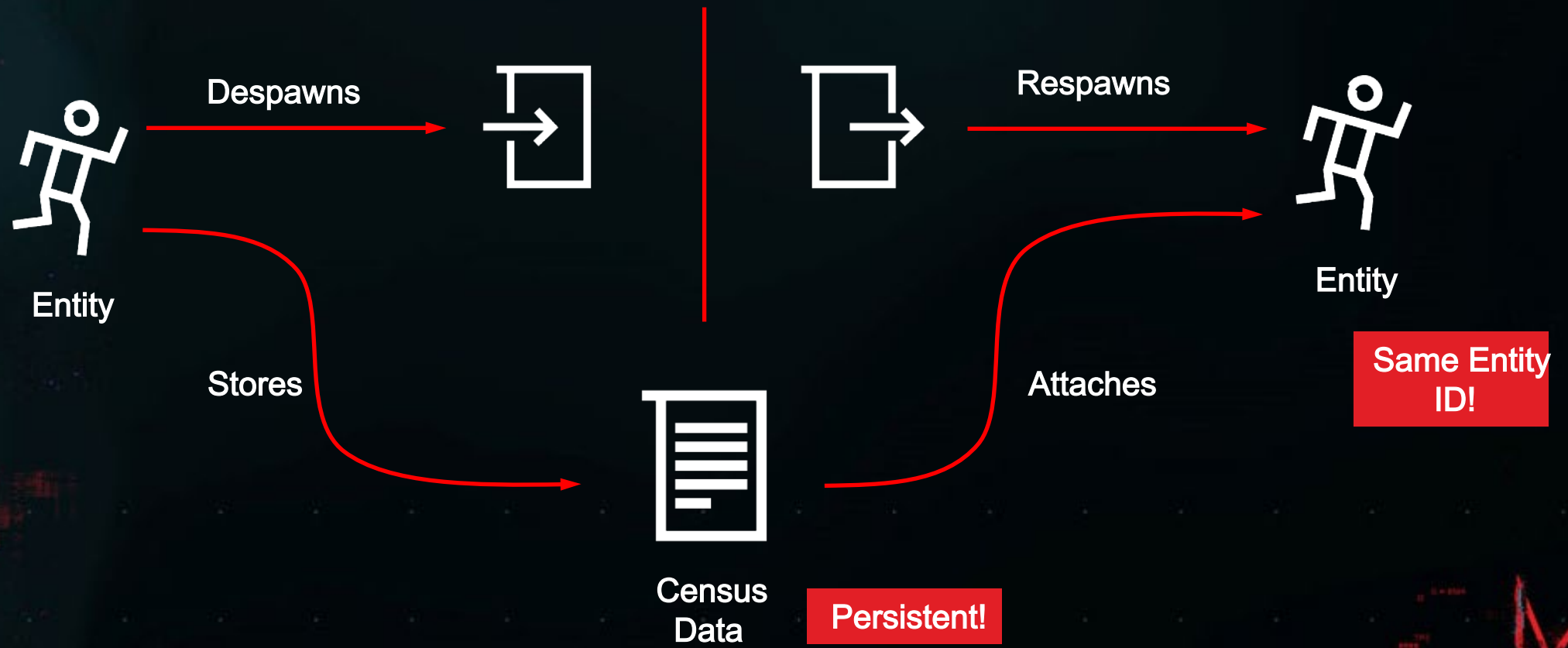
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Persistence



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Dynamic Scheduling

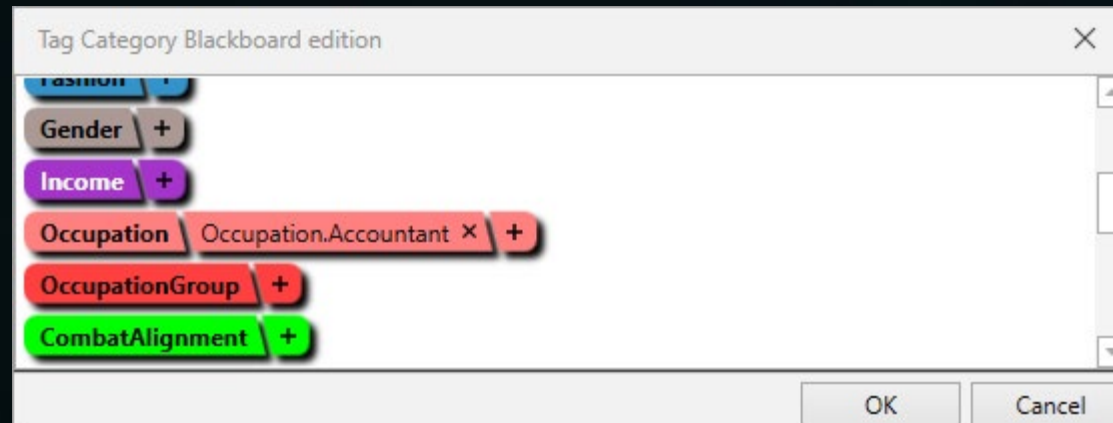
- / All character schedules are **dynamically generated**
- / Three step process:
 1. Determine the current activity and schedule it
 2. Determine what other activities the character might like to do
 3. Find places for the character to perform their activities



Scheduling Contracts

/ **Contracts** define the nature of an activity

/ E.g., the contract `Work.Accountant` is gated by the occupation field:



/ Contracts are scheduled in the world to realize the activity

Relationship Contracts

- / A relationship is a special contract with two participants
- / Relations can be dynamically created
 - / Use dynamic profile constraints for consistency
- / Schedule it in the world to realize the relationship



Activities

/ Visible Activities

/ Performing an animation in the world

/ Relationships user & person synched animations

/ A contract is realized by scheduling an activity



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Despawned Activities

- / Doors allow for despawned activities
- / Allow for narratively interesting contracts without animations
 - / E.g. meeting with a therapist

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Alibi Generation

- / First step in schedule generation
- / Justify the character's current actions

Rule: Schedule must never contradict the visible actions of an NPC



Scheduling Structure

- / Day is divided into 24 hour slots
- / Assign Contracts for the following:
 - / 1 Work Activity
 - / 1 Rest Activity
 - / 3 or 4 Leisure Activities
 - / At least one leisure must be a relation contract
- / Travel slot between all scheduled activities

Time	Activity
00:00 – 07:00	Rest
07:00	Travel
08:00 – 16:00	Work
16:00	Travel
17:00	Leisure
18:00	Travel
19:00	Leisure (meeting)
20:00	Travel
21:00 – 23:00	Leisure
23:00	Travel

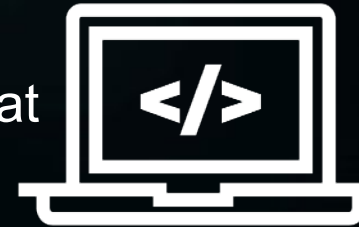
Scheduling Activities

- / Extremely Data Intensive
- / Every activity in the world needs tagging data
- / Optimize activity selection
 - / Visible vs despawned
 - / Schedule locality
 - / Location based

General Stats	
# of Locations	4143
# of Activities (total)	96100
# of Activities (visible)	89386
# of Activities (despawne)d	6714
# of Activities (2 person synch	26269

Schedule Generation Performance

- / Scheduling does not require immediacy
 - / Can aggressively time-slice and spread work across many frames
 - / Initially, requests still took too long to complete (2s)
- / Spikes were common
 - / Some activities can be done at 10 locations, others can be done at 10 000
- / Solution - Cache 38MB of schedule queries
- / Result: Worst case schedule queries return in < 1s



Schedule Following

- / Not the emphasis of the game
 - / Following people is boring gameplay
- / Baseline simulation goal was to ensure characters can successfully move between activities
 - / Characters walk or take the tube to reach next activity
- / 90% success rate for characters to reach their next activity on time

Jacqueline Whalen



Investigate Recruitment Leads to raise their support for DedSec

20:00
21:00



Identified an Albion war criminal





Friend's EPC records stored at US Embassy



SCHEDULE

0:00
8:00



Acting as a consultant at Boxtown



9:00
11:00



Protesting at Parliament Square Gardens



12:00
14:00



Volunteering in Westminster



15:00
23:00



Sleeping at Leake Street



Investigate

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Scheduling Guards

- / Guard and combat units can't naively follow schedules
 - / Would break LD patterns and missions
- / Solution: Guards ignore their schedule while guarding
 - / On despawn they become regular schedule followers



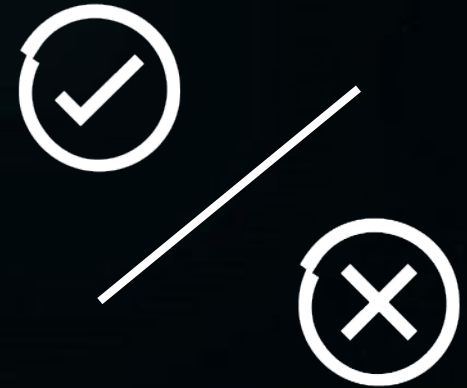
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Scheduling- What worked and what didn't

- / Despawned Activities were essential during development
 - / They allowed us to activate scheduling at a very early stage, without waiting for the world teams to place properly tagged interactions
- / Tagging errors can be dangerous
- / Dynamic Scheduling has tremendous hidden complexity
 - / It impacts all aspects of the game that use characters
 - / Each aspect comes with a set of edge cases



Roadmap

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Census Computations

- / Characters do not require all Census information at all times
- / **Upresing** provides a level of detail system for Census
 - / “Increasing the resolution of our generation and simulation”

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CensusUpresing

Stage0	Partially refined profile, character mode Default state after spawning.
Stage1	Fully refined profile. Persistent with a characterschedule.
Stage 2	Relations, recruitment mission, character bio facts. Fully realized.

Stage 0—New Spawns

/ Requirements:

- / Engine architecture requires spawning tasks to resolve in a single frame
- / Census profile fields can be constrained in data in any order

/ Perform a partial profile refinement

- / Limit spawn refinement to fields connected to player facing assets, and those needed immediately for the character's role in the game

GAIN: Partial refinement on spawn
reduces CPU cost by ~~20~~%

Stage 1 Upres



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Stage 1 Upres

- / Performs a full profile refinement

- / Additional bio information

- / Name

- / Income

- / Age

- / Dynamically creates a schedule

- / Makes the character persistent

- / Adds gameplay abilities

- / Trait information for the profiler



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Stage 2Upres



Peter Papanikolaou
UX Designer

Previous arrest for cyber crimes

Recent Events
Liked a video about DedSec stopping human trafficking

Demographics

- Age: 34
- Occupation: UX Designer
- Salary: £81400

Associates

- Melissa Papanikolaou (Sister)
- Michelle Papanikolaou (Cousin)

Metadata

- Searched for: "how to never interact with anyone"
- Member of the Conservative Party
- Runs Cornish pasty review blog
- Born in Cambridge, England
- Recently purchased: counterfeit handbag

Currently Recruiting
X View Mission

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Stage 2 Upres

- / Adds relations
- / Adds metadata
- / Adds recruitment missions
 - / These too can create additional characters to populate the mission
- / Computationally Expensive



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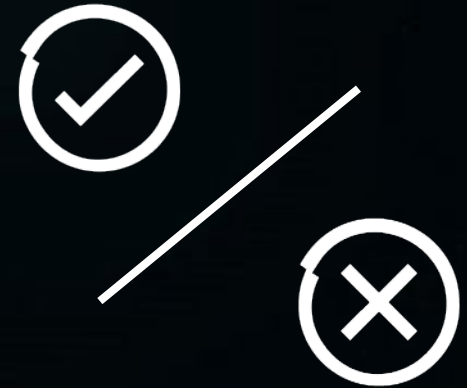


Census Operations

- / All Census computations are structured as **Operations**
 - / Profile Refinement, Schedule Generation, ~~State~~ etc.
- / Operations are processed by a central **Operations Manager**
- / Each operation can be ~~triggered~~ **initiated** as needed
 - / Custom callback registration allows immediate reaction without polling
- / Single point for operations allows for:
 - / Locking NPCs
 - / Prioritizing operations
 - / Replication

Uprising—What Worked and Didn't

- / Uprising was highly successful as a concept and a technical solution
 - / Core to effective performance management and resource usage
- / A staged upresprocess was a major win
 - / Uprising was originally all or nothing
 - / This occasionally constrained design, but was never a big problem



Roadmap

Census



- Character Generation
- / Simulation Layer
- / Operation Management
- / Recruitment Layer*
- / Wrap-up Example

* Credit: Bruce McNeish, Game Systems Programmer

Recruitment

- / Playas-Anyone builds on the framework provided by Census
- / Recruitment is the primary link between the simulation and gameplay

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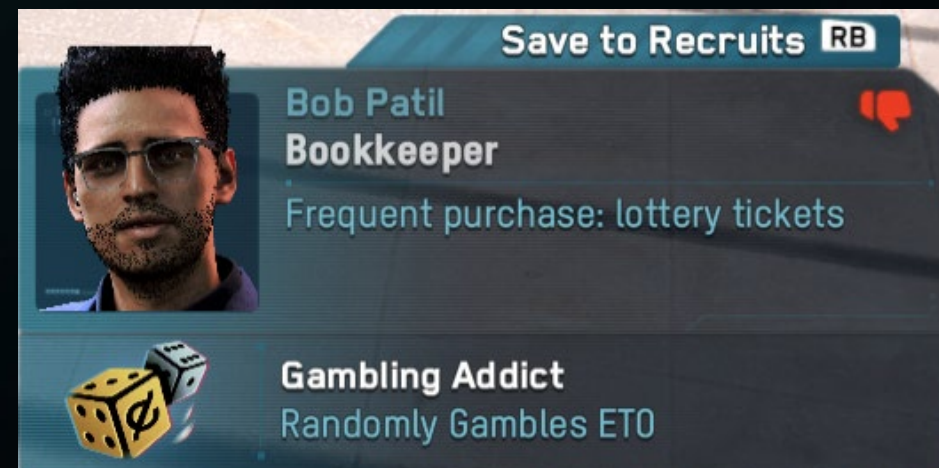
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DedSec Affinity

- / **Affinity** is the basis of the recruitment system
 - / Provides a running tabulation of the impact of player actions
- / How much does the character like DedSec?
 - / Full affinity? They will join the cause!
 - / Zero affinity? They will oppose DedSec and may even take revenge



Character Memories

- / The vehicle for affinity change
 - / Makes affinity concrete
- / Very lightweight system built on the persistent foundation
 - / Memories persist with the character



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Memory Features

- / Memory reactions allow the player to feel their impact on the world
- / Memories propagate across relations
 - / Help out a person. Not only will they like you more, but so will their friends and family

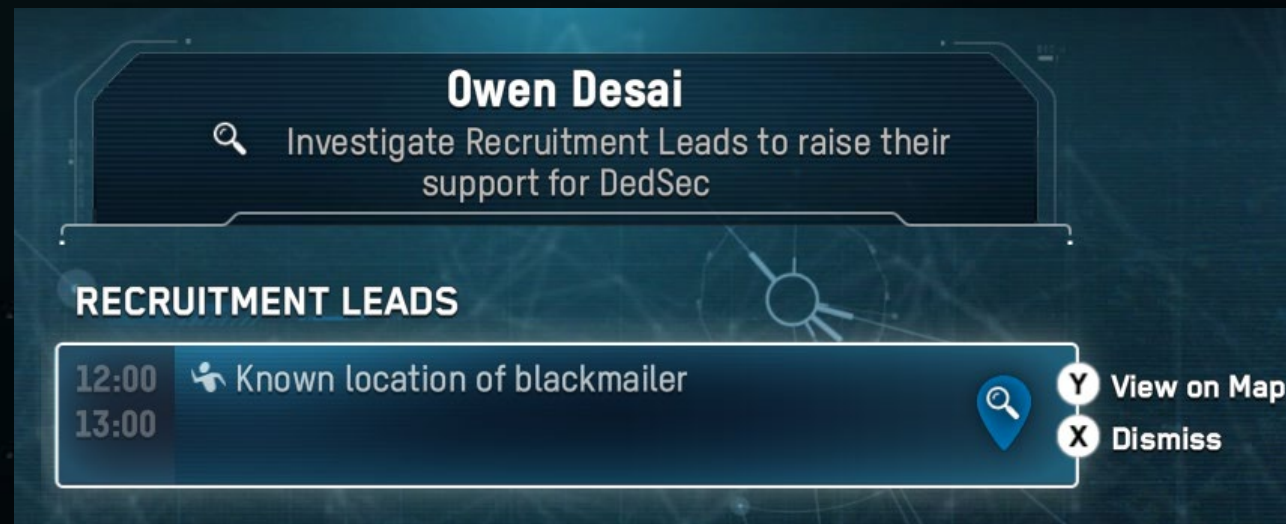


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Recruitment Intrigues

- / **Intrigues** provide a structured way to increase the affinity of a character
- / Onebeat missions designed to draw the player into the open world
- / Accessed through the deep profiler

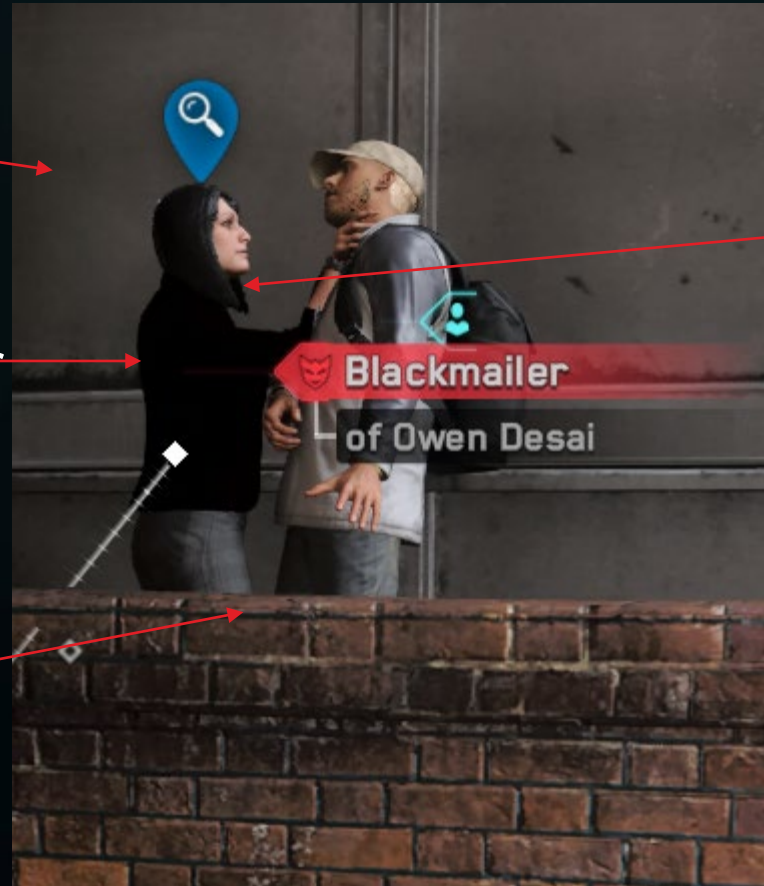


Recruitment Intrigues

Contract: BlackmailerVictim

Stage 1 Relation: Blackmailer

Scheduled Meeting



Intrigue Resolved?
Blackmailer = {dead, injured, arrested}

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Owen Desai
Cosmetologist

Concussed paparazzo with own camera

 View Summary

Recent Events

- 🟢 Recruited by Operative Nick Charles
- 🟡 Their blackmailer was hospitalised by DedSec
- 🟢 Liked a video about DedSec stopping human trafficking

Demographics

- └ Age: 37
- └ Occupation: Cosmetologist
- └ Salary: £24,300

Associates

- └ Joyce Desai (Wife)
- └ Maria Jimenez (Former Blackmailer, injured)

Metadata

- └ £5,000 in debt
- └ Subscribes to multiple fashion vlogs

Intrigue Memory + Affinity Gain

NEW OPERATIVE

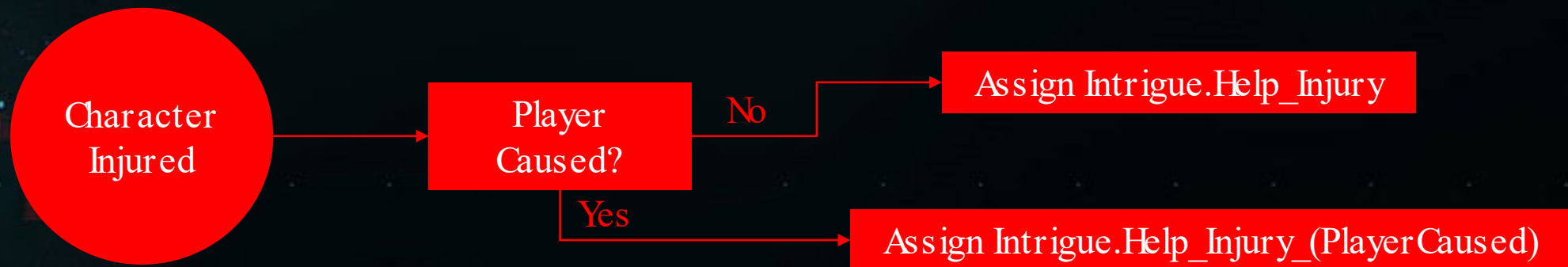
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Systemic Awareness

- / How aware is the character receiving the memory?
 - / First-order actions should always create a memory
 - / Secondorder actions should give a memory where possible
 - / The player controlling a drone that injures a character
 - / Higher order effects are too hard to capture
- / The more awareness of history, the better the experience



Recruitment Missions

- / Balances systemic with more narrative content
 - / Not mandatory can still complete recruitment systemically
- / Assign consistent recruitment missions by using character profiles



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Recruitment—What Worked and What Didn't

- / Affinity as a global concept allowed us to tie together many disparate systems (gameplay, mission events, open world content)
- / Intrigues were a systemically simple addition to Census, with most programming effort going to UX and Narrative content
 - / Unfortunately this resulted in duplication of existing mission code
- / The marriage between systemic recruitment and the recruitment missions was uneasy
 - / Many rounds of iteration!



Roadmap

Census



- Character Profiles
- / Simulation Layer
- / Level of Detail
- / Recruitment
- / Wrap-up Example

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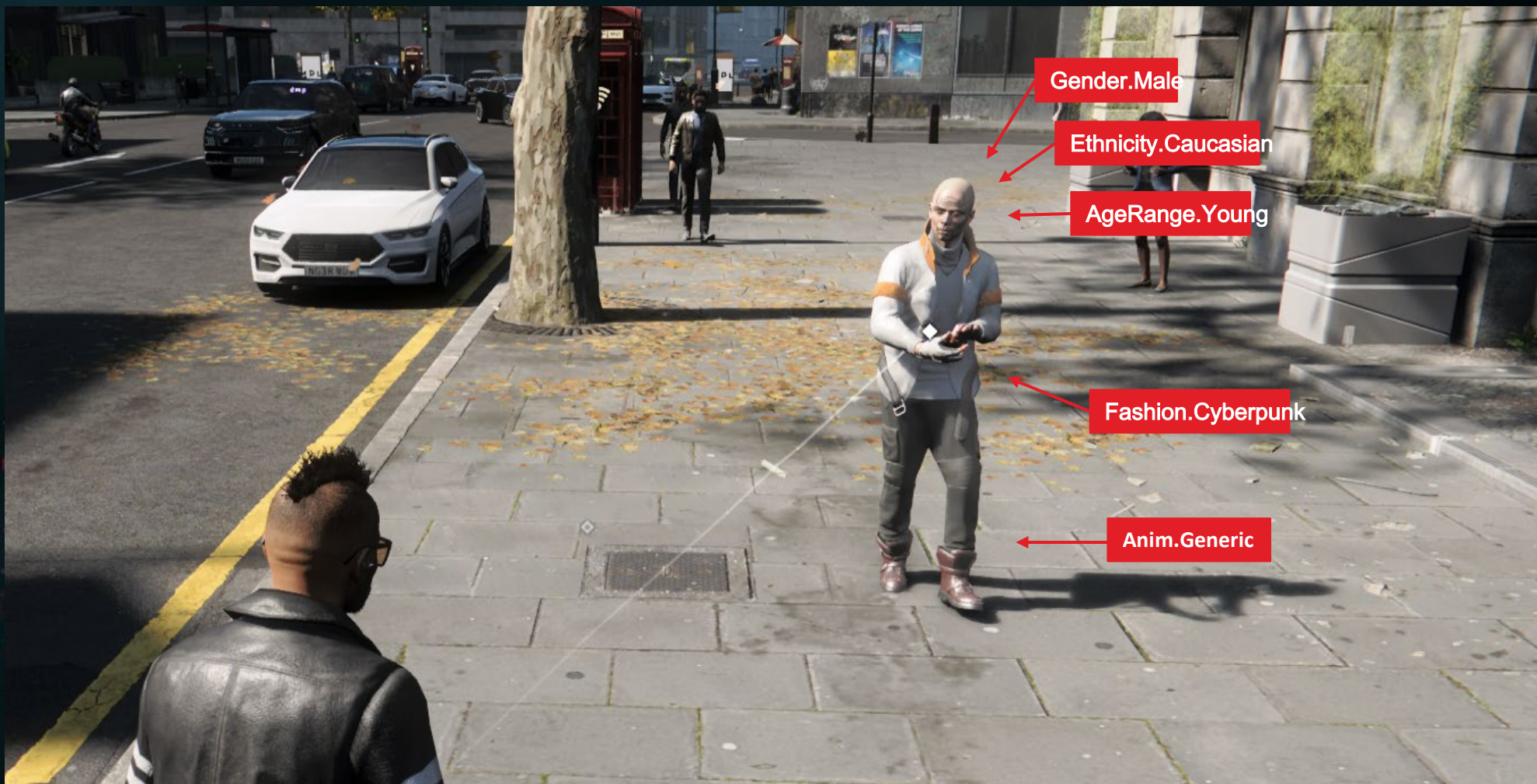
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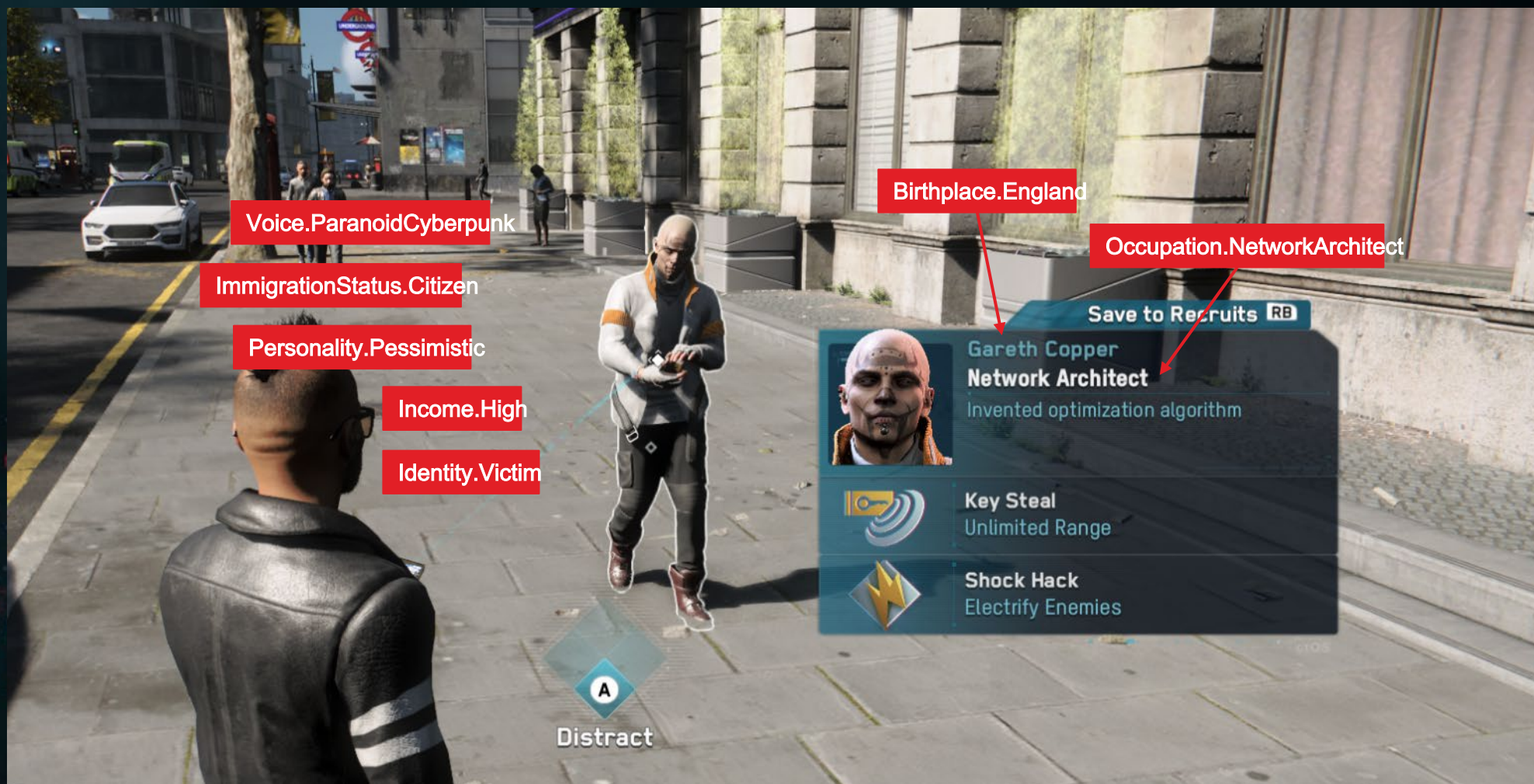
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Gareth Copper
Network Architect

Invented optimization algorithm

Recent Events

Liked a DedSec post about unchecked Albion authority

Demographics

- Age: 18
- Occupation: Network Architect
- Salary: £74200

Associates

- John Chowdhury (Blackmailer)
- Sharon Tembo (Therapist)

Metadata

- Collects kaiju figurines
- Recovering meth addict
- Holds Ph.D in computer science
- Purchased Skye Larsen memoir
- Owes £25,000 in credit card debt

Currently Recruiting

- X View Mission
- Y Deep Profile

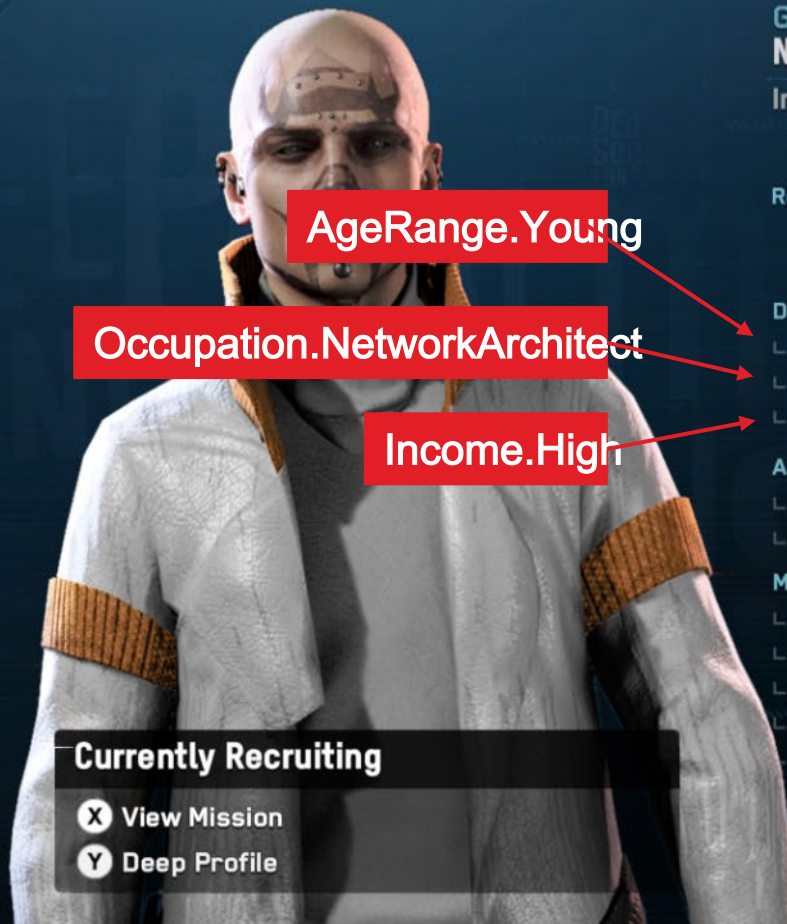
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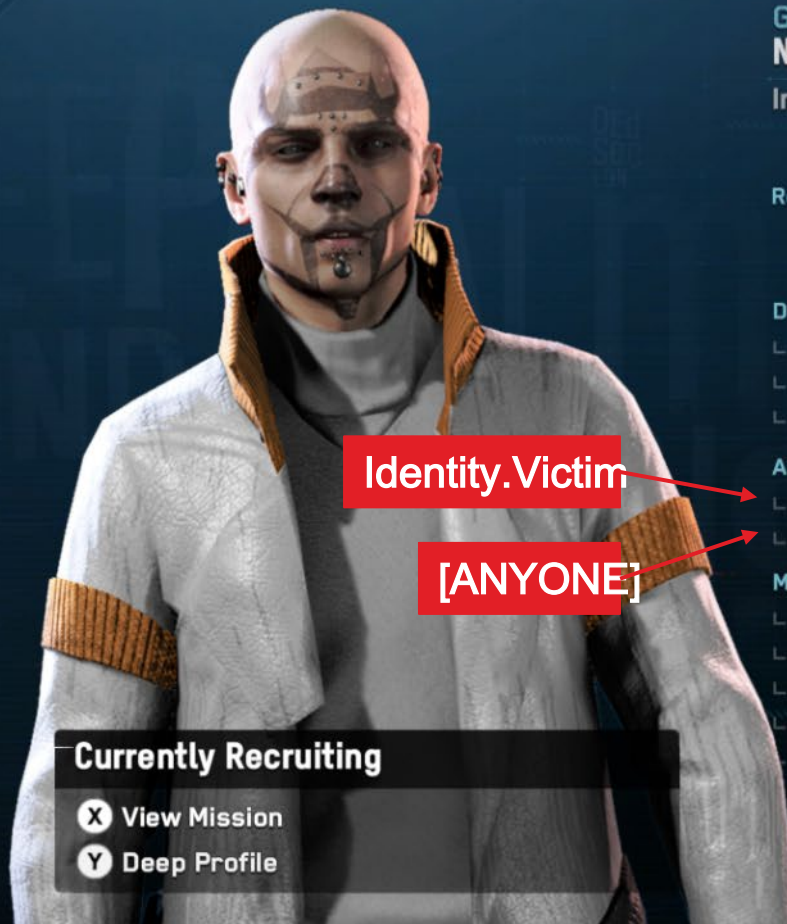
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Identity.Victim

[ANYONE]

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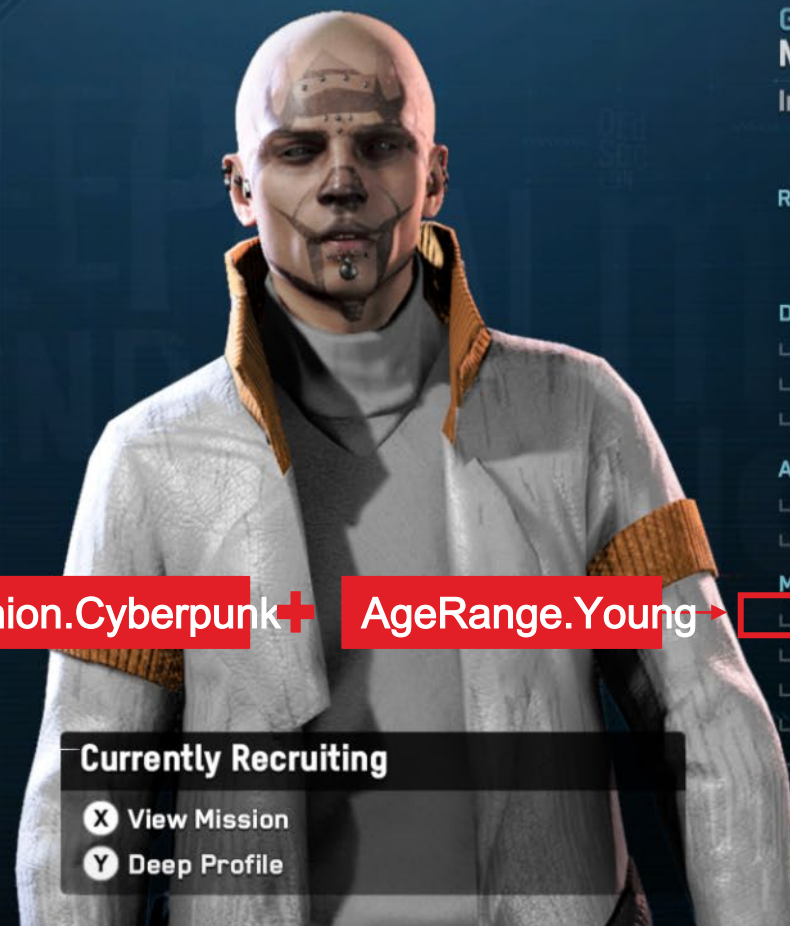
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Fashion.Cyberpunk+

AgeRange.Young→

Currently Recruiting

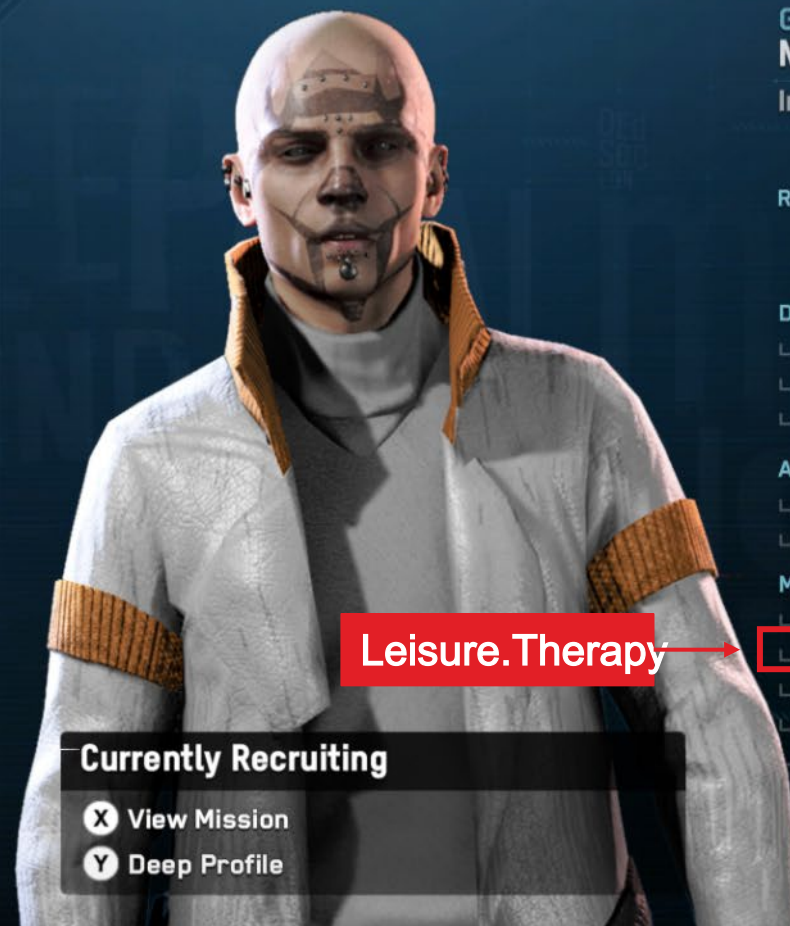
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Liked a DedSec post about unchecked Albion authority

Demographics

- Age: 18
- Occupation: Network Architect
- Salary: £74200

Associates

- John Chowdhury (Blackmailer)
- Sharon Tembo (Therapist)

Metadata

- Collects kaiju figurines
- Recovering meth addict
- Holds Ph.D in computer science
- Purchased Skye Larsen memoir
- Owes £25,000 in credit card debt

Currently Recruiting

- X View Mission
- Y Deep Profile

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LEGION



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POTENTIAL RECRUITS



Affinity: Positive

Gareth Copper Network Architect

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Gareth Copper

Investigate Recruitment Leads to raise their support for DedSec

RECRUITMENT LEADS

14:00 Known location of blackmailer
15:00

SCHEDULE

1:00 Sleeping in St. James
9:00

10:00 Waiting at Broca Tech
11:00

12:00 Attending rehab with Sharon Tembo (Therapist)
13:00

16:00 Working at an office
0:00

X Investigate

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X Investigate

Income.High

Occupation.NetworkArchitect

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Working at an office

Fashion.Cyberpunk →

Contract.Blackmail

Contract.Therapy

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Summary

- / Census is a powerful system used to generate internally consistent characters
- / Through character persistence and schedules, these characters can be meaningful participants in the world instead of mere background
- / Upressing effectively manages both performance and increasing feature complexity
- / Affinity and Memory Systems tie characters to player actions at a deep level
- / Recruitment process builds on these systems to enable Play Anyone

Thanks!



Census Team

Scheduling & Persistence **Stuart Rudderham** Game System Programmer
Census **Farbod Teedaynoor** Game Systems Programmer
Recruitment **Bruce McNeish** Game Systems Programmer
Direction **Martin Walsh** Technology Director
Design **Liz England** Game Design

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Thanks!



Census Team

Character Profiles and Operations **Ferbod Teedaynoor** Game Systems Programmer
Scheduling & Persistence **Stuart Rudderham** Game Systems Programmer
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Recasting

- / Recasting is the act of taking existing characters and placing them into interesting situations
 - / A drug dealer that you've previously met may become the drug dealer in a new mission
 - / The person you were helping may be cast into a world event where they are being mugged and you have a chance to save them and increase their affinity
- / Effective tool to show players the impact of their actions

Intel System

- / Aids in discoverability of valuable characters
- / Helps find specialty characters when needed
 - / When your operative is arrested for the first time, push an intel on a lawyer that can help free your operative

Adversaries

- / Simple to add
- / Kill/injure/arrest/deduce? They become an adversary
- / Special banner, achievement to neutralize them

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Localisation

- / Census schedule and memory strings are dynamically constructed from templates
- / Each template contains {tags}
 - / E.g. `{Actor.Title} {Actor.FullName}'s {Relation.type} was rescued by {DedSec}`
- / Pass into a central tag substitution algorithm, recursively replace tags with data
 - / `{Actor.FullName}` becomes `{Actor.FirstName}{Actor.LastName}`
 - / E.g. `Operative Jim Smith's Cousin was rescued by {DedSec}`
- / Add extra fields for gender/noun agreement across other languages