COMP 4303
Video Game AI

MEMORIAL UNIVERSITY

Lecture 15
Intro to StarCraft
BWAPI – Brood War API
Intro to Starcraft AI

Starcraft / BWAPI Links

- BWAPI API Documentation
  - https://bwapi.github.io/annotated.html
  - https://bwapi.github.io/class_b_w_a_p_i_1_1_game.html
  - https://bwapi.github.io/class_b_w_a_p_i_1_1_unit_type.html
  - https://bwapi.github.io/class_b_w_a_p_i_1_1_unit_interface.html
- Liquipedia Articles
  - https://liquipedia.net/starcraft/Main_Page
  - https://liquipedia.net/starcraft/StarCraft
  - https://liquipedia.net/starcraft/Definitions
  - https://liquipedia.net/starcraft/Units
  - https://liquipedia.net/starcraft/Buildings
  - https://liquipedia.net/starcraft/Portal:Beginners

StarCraft

- Blizzard - 1998
- Best Selling RTS of all time
- Millions of players worldwide
- Professionally played - 2001
- BroodWar C++ API (BWAPI)
  - Read StarCraft Memory
  - Issue Commands to Game

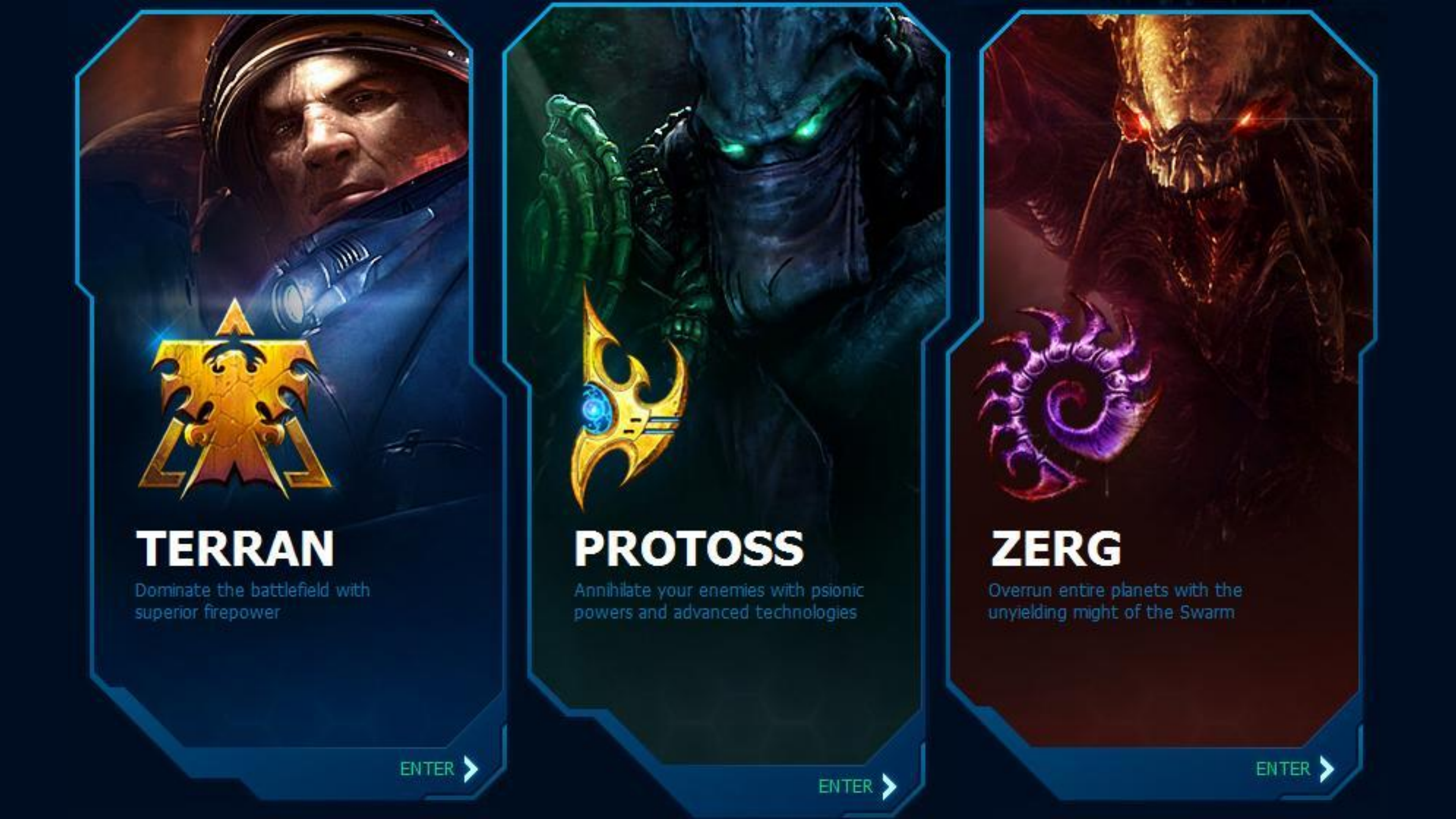
Real-Time Strategy

- War-like Simulation
- Single / Multiplayer Games

- Most RTS Games:
  - Gather Resources
  - Build Town / Army
  - Combat With Enemies

Starcraft Strategy

- 3 main categories of strategy in RTS
- Attack (Rush / Aggressive)
  - Attack your enemy early in the game
- Defend (Turtle / Bunker)
  - Build defenses to fend off attacks
- Expand (Econ / 2nd Base)
  - Build early expansion for more income
- Rock-Paper-Scissors Effect
  - Attack > Expand > Defend > Attack …



TERRAN

Dominate the battlefield with superior firepower

PROTOSS

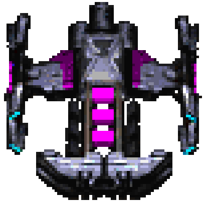
Annihilate your enemies with psionic powers and advanced technologies

ZERG

Overrun entire planets with the unyielding might of the Swarm

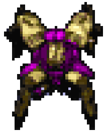
Terran

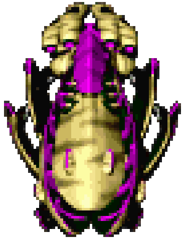
- ‘Human’ like race, likes mech units
- Buildings can lift and be re-placed, have addons
- Early game unit: Marine
  - Low hp, ranged attack / hits flying
  - Good all game, Medic can heal them
- Mid game unit: Siege Tank
  - Siege mode – can’t move but attacks far
- Late game unit: Battlecruiser
  - Huge flying ship, loads of hp



Protoss

- Civilized alien race, expensive units
- Units have shields that regenerate
- Buildings require ‘power’ from pylons
- Early game units: Zealot / Dragoon
  - Zealot: Tanky melee unit
  - Dragoon: Tanky ranged unit
- Mid game unit: High Templar
  - Casts psionic storm, aoe damage
- Late game unit: Carrier
  - Huge flying ship, shoots out smaller ships



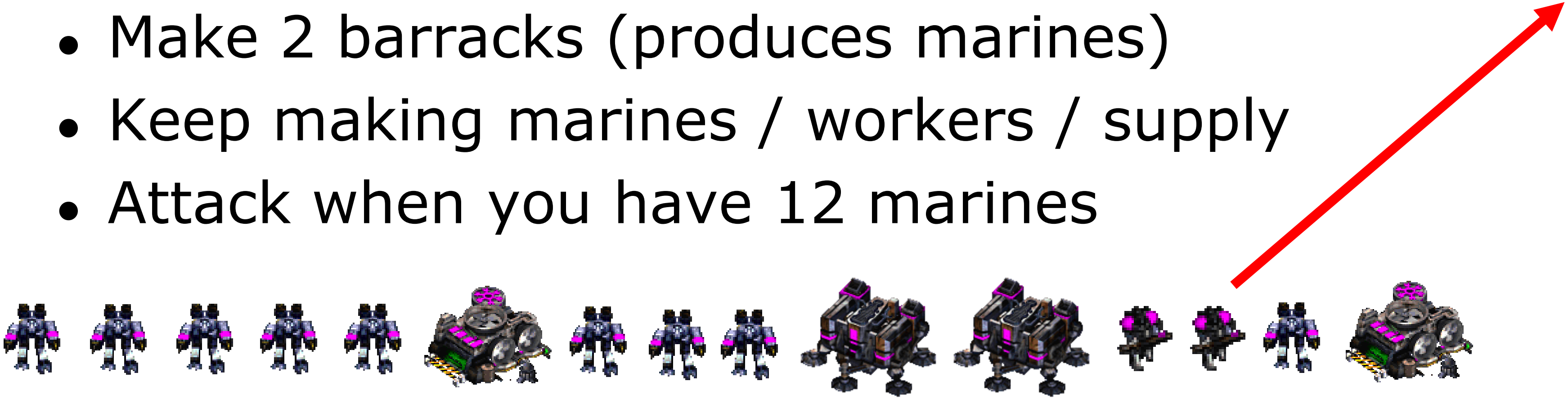


Zerg

- Uncivilized alien race, make many units
- Units regenerate HP, morph / eggs
- Must build buildings on ‘creep’
- Early game units: Zergling
  - Very cheap, fast, can rush easily
- Mid game unit: Mutalisk
  - Fast moving flying unit, micro heavy
- Late game unit: Ultralisk / Devourer
  - Ultralist: Huge tanky melee unit
  - Devourer: Spell caster / dark swarm

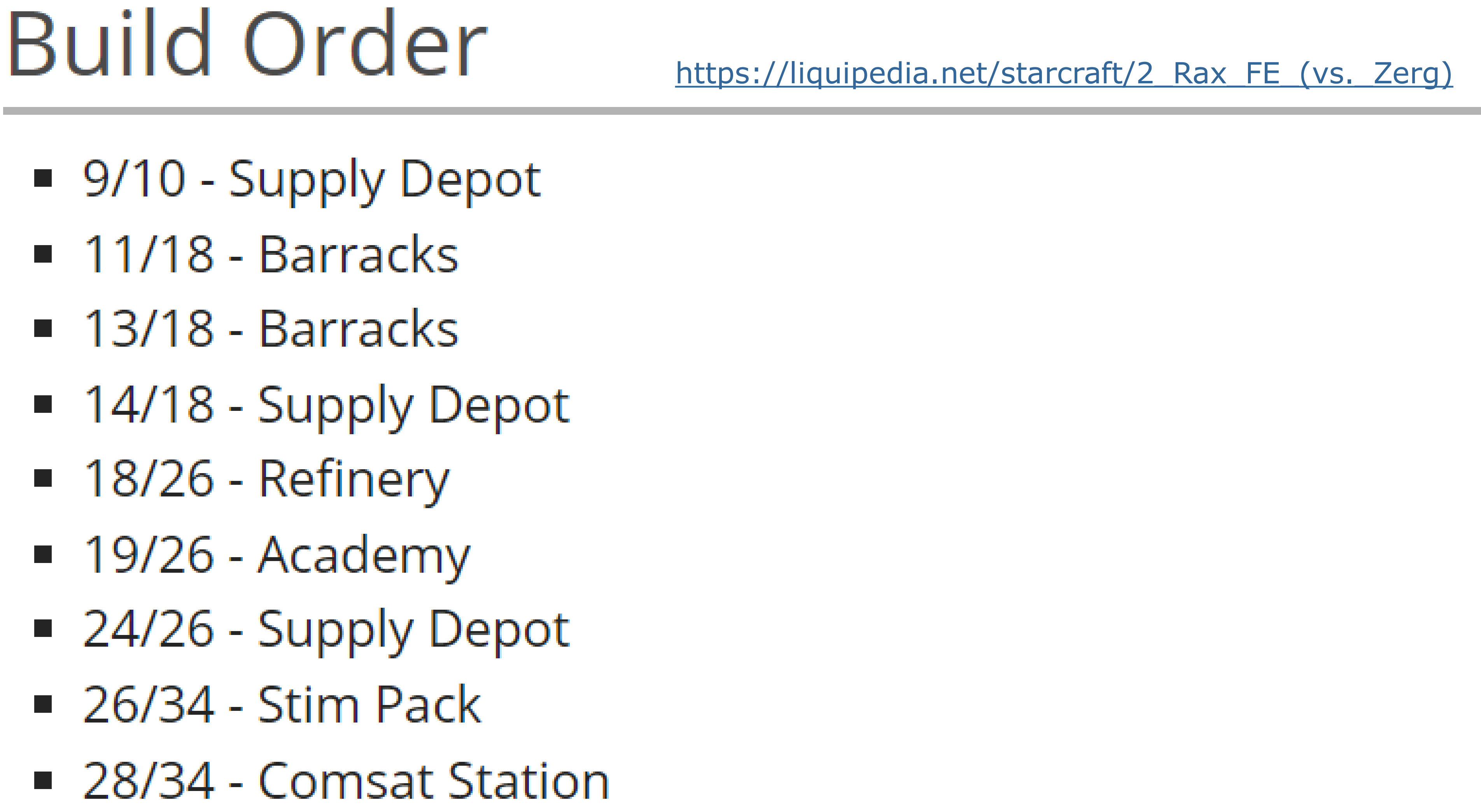
Example Terran Game

- Keep making workers until 9
- Make a supply depot (increase supply)
- Make workers until you have 12
- Make 2 barracks (produces marines)
- Keep making marines / workers / supply
- Attack when you have 12 marines



What is a Build-Order?

- Sequence of economic actions
- List of buildings / units to build in order
- Players memorize ‘opening books’



Build Order

https://liquipedia.net/starcraft/2_Rax_FE_(vs._Zerg)

- 9/10 - Supply Depot
- 11/18 - Barracks
- 13/18 - Barracks
- 14/18 - Supply Depot
- 18/26 - Refinery
- 19/26 - Academy
- 24/26 - Supply Depot
- 26/34 - Stim Pack
- 28/34 - Comsat Station

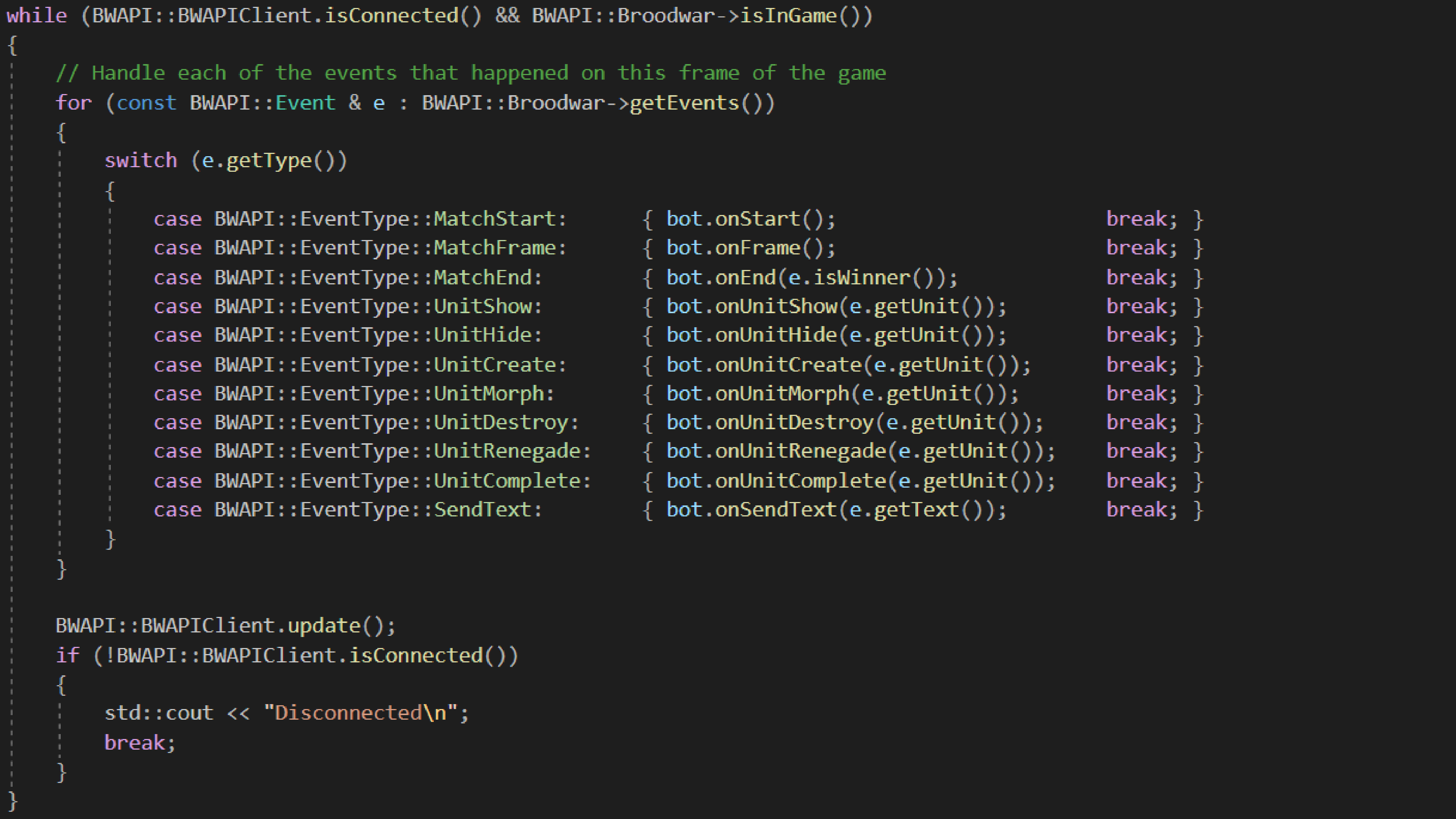
Build-Order Problems

- What army to construct?
- How to predict enemy army based on current observation?
- Where to place buildings?

- Example: use human knowledge or machine learning to predict enemy composition

Brood War API (BWAPI)

- Used to talk to Starcraft with C++
- Injects a .dll into the Starcraft process
- Communicates with your C++ program
- When game starts, BWAPI connects
- BWAPI records events, triggers your code
    - onStart(), onFrame(), onUnitDestroy()
- When game is over, BWAPI disconnects



```
while (BWAPI::BWAPIClient.isConnected() && BWAPI::Broodwar->isInGame())
{
    // Handle each of the events that happened on this frame of the game
    for (const BWAPI::Event & e : BWAPI::Broodwar->getEvents())
    {
        switch (e.getType())
        {
            case BWAPI::EventType::MatchStart:      { bot.onStart();                      break; }
            case BWAPI::EventType::MatchFrame:      { bot.onFrame();                      break; }
            case BWAPI::EventType::MatchEnd:        { bot.onEnd(e.isWinner());            break; }
            case BWAPI::EventType::UnitShow:        { bot.onUnitShow(e.getUnit());        break; }
            case BWAPI::EventType::UnitHide:        { bot.onUnitHide(e.getUnit());        break; }
            case BWAPI::EventType::UnitCreate:      { bot.onUnitCreate(e.getUnit());      break; }
            case BWAPI::EventType::UnitMorph:       { bot.onUnitMorph(e.getUnit());       break; }
            case BWAPI::EventType::UnitDestroy:     { bot.onUnitDestroy(e.getUnit());     break; }
            case BWAPI::EventType::UnitRenegade:    { bot.onUnitRenegade(e.getUnit());    break; }
            case BWAPI::EventType::UnitComplete:    { bot.onUnitComplete(e.getUnit());    break; }
            case BWAPI::EventType::SendText:        { bot.onSendText(e.getText());        break; }
        }
    }

    BWAPI::BWAPIClient.update();
    if (!BWAPI::BWAPIClient.isConnected())
    {
        std::cout << "Disconnected\n";
        break;
    }
}
```

STARTcraft

- StarterBot for C++ / BWAPI
- Easy to set up / use (3 minutes)
- Self-documenting code tutorial

- https://github.com/davechurchill/STARTcraft

Starcraft Unit Commands

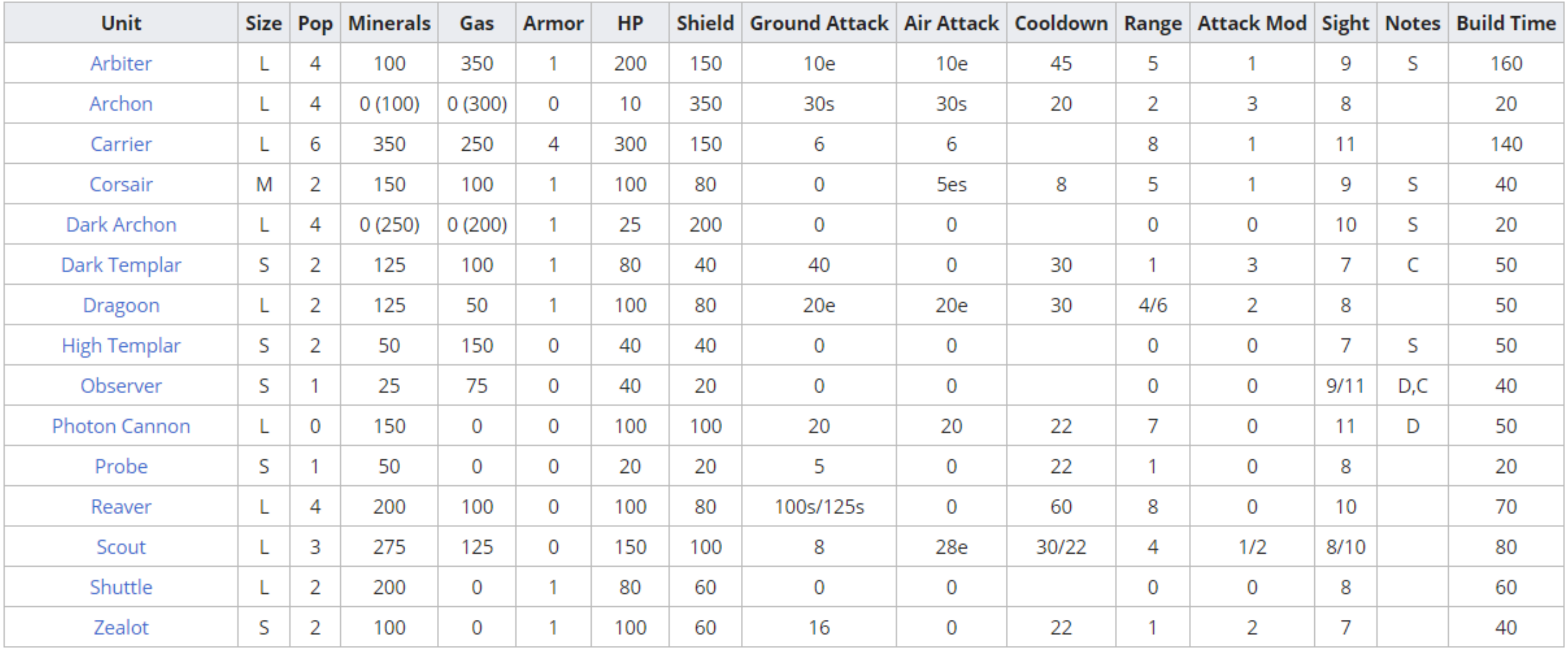
- Each unit can be given commands
- Cannot control enemy units
- Unit command examples
  - Move, Attack, Patrol, Build, Stop
- Unit commands take parameters
  - Move(pos), Attack(unit), Build(type, pos)
- Let’s look at BWAPI examples

```
// https://bwapi.github.io/class_b_w_a_p_i_1_1_unit_interface.html
void unitCommands(BWAPI::Unit unit)
{
    BWAPI::Position desiredPosition(400, 300);
    unit->move(desiredPosition);
    unit->rightClick(desiredPosition);
    unit->attackMove(desiredPosition);
    unit->patrol(desiredPosition);
    BWAPI::Unit enemyUnit = getEnemyUnitTarget();
    unit->attack(enemyUnit);
    unit->rightClick(enemyUnit);
    unit->burrow() // Zerg units with burrowing
    unit->stop();
}
```

Starcraft Unit Properties

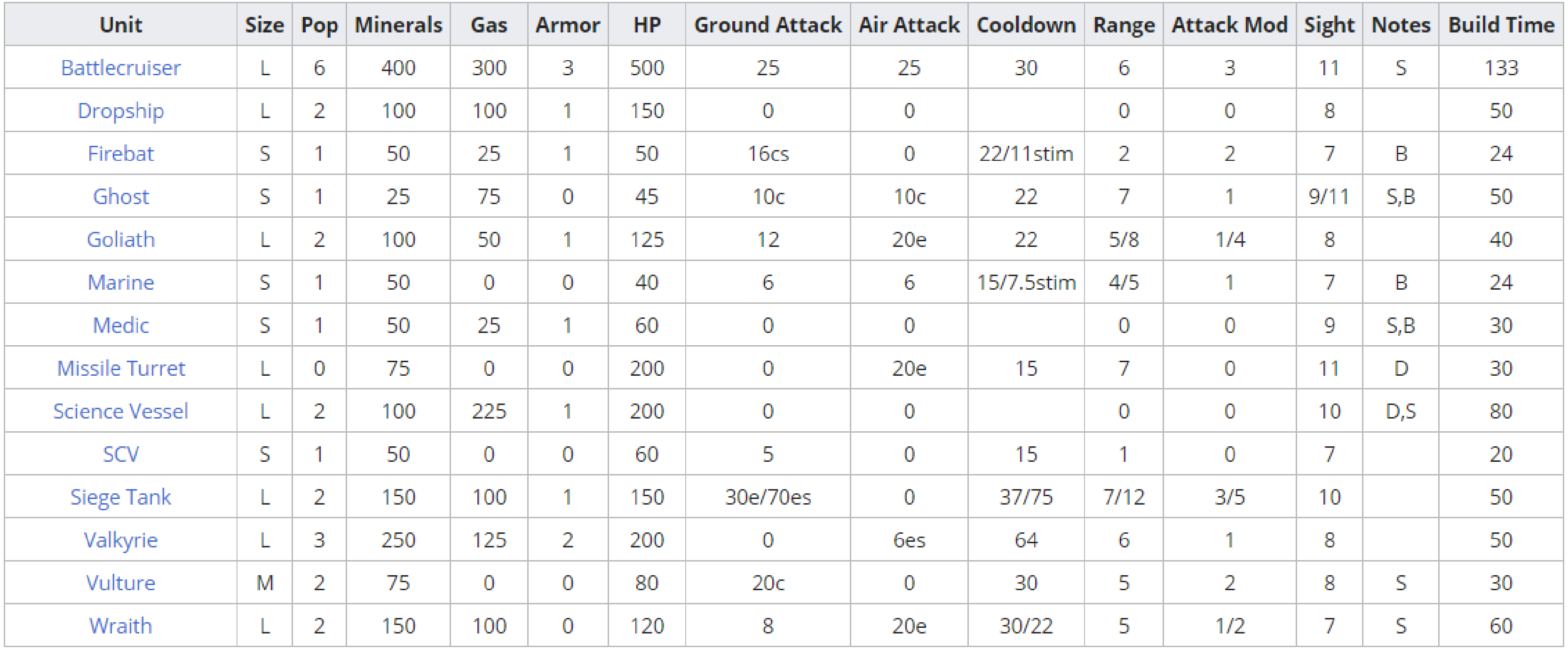
- Each Unit has a number of properties
- Unit Instance properties - BWAPI::Unit
  - Position, Health, Shields, Player, UnitType
- Unit Type properties - BWAPI::UnitType
  - MaxHealth, Damage, WeaponType, Flying
  - MaxSpeed, Acceleration, Size
  - MineralPrice, GasPrice, Supply, VisionRadius

Protoss Unit Properties



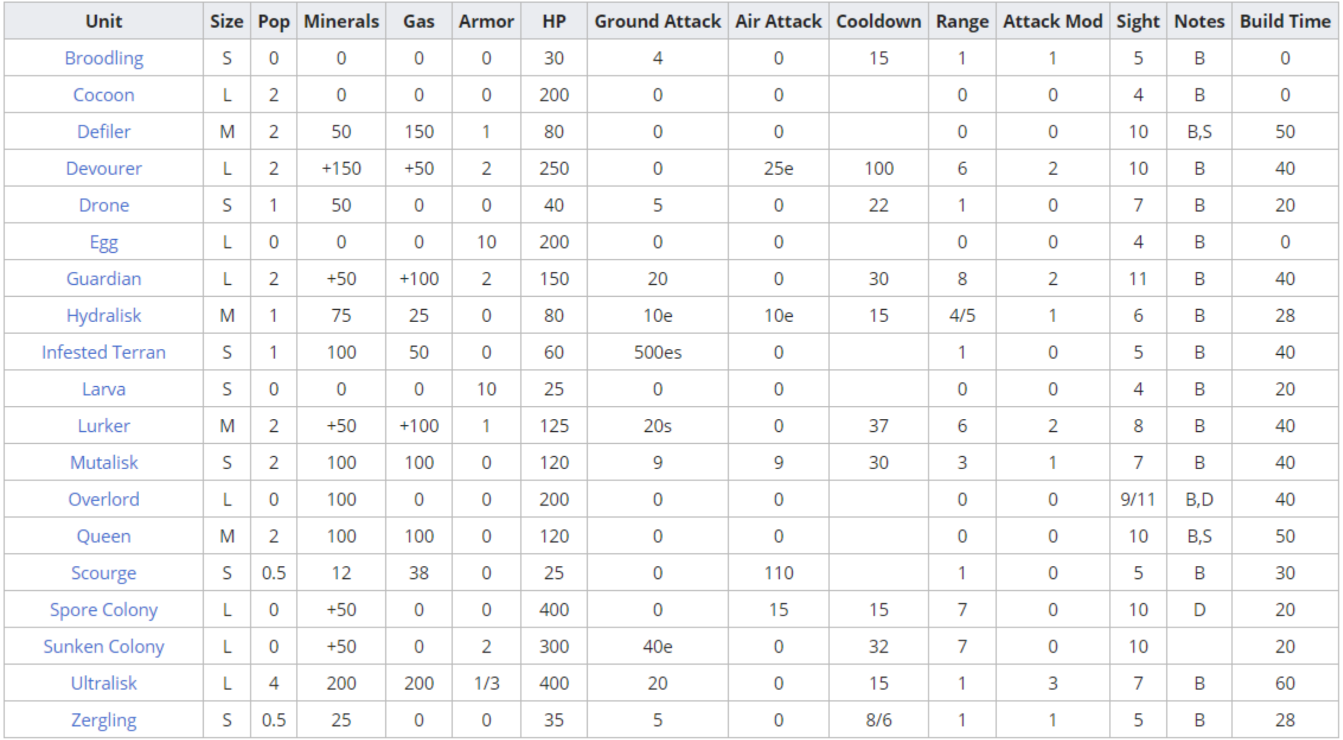
Unit	Size	Pop	Minerals	Gas	Armor	HP	Shield	Ground Attack	Air Attack	Cooldown	Range	Attack Mod	Sight	Notes	Build Time
Arbiter	L	4	100	350	1	200	150	10e	10e	45	5	1	9	S	160
Archon	L	4	0 (100)	0 (300)	0	10	350	30s	30s	20	2	3	8		20
Carrier	L	6	350	250	4	300	150	6	6		8	1	11		140
Corsair	M	2	150	100	1	100	80	0	5es	8	5	1	9	S	40
Dark Archon	L	4	0 (250)	0 (200)	1	25	200	0	0		0	0	10	S	20
Dark Templar	S	2	125	100	1	80	40	40	0	30	1	3	7	C	50
Dragoon	L	2	125	50	1	100	80	20e	20e	30	4/6	2	8		50
High Templar	S	2	50	150	0	40	40	0	0		0	0	7	S	50
Observer	S	1	25	75	0	40	20	0	0		0	0	9/11	D,C	40
Photon Cannon	L	0	150	0	0	100	100	20	20	22	7	0	11	D	50
Probe	S	1	50	0	0	20	20	5	0	22	1	0	8		20
Reaver	L	4	200	100	0	100	80	100s/125s	0	60	8	0	10		70
Scout	L	3	275	125	0	150	100	8	28e	30/22	4	1/2	8/10		80
Shuttle	L	2	200	0	1	80	60	0	0		0	0	8		60
Zealot	S	2	100	0	1	100	60	16	0	22	1	2	7		40

Terran Unit Properties



Unit	Size	Pop	Minerals	Gas	Armor	HP	Ground Attack	Air Attack	Cooldown	Range	Attack Mod	Sight	Notes	Build Time
Battlecruiser	L	6	400	300	3	500	25	25	30	6	3	11	S	133
Dropship	L	2	100	100	1	150	0	0		0	0	8		50
Firebat	S	1	50	25	1	50	16cs	0	22/11stim	2	2	7	B	24
Ghost	S	1	25	75	0	45	10c	10c	22	7	1	9/11	S,B	50
Goliath	L	2	100	50	1	125	12	20e	22	5/8	1/4	8		40
Marine	S	1	50	0	0	40	6	6	15/7.5stim	4/5	1	7	B	24
Medic	S	1	50	25	1	60	0	0		0	0	9	S,B	30
Missile Turret	L	0	75	0	0	200	0	20e	15	7	0	11	D	30
Science Vessel	L	2	100	225	1	200	0	0		0	0	10	D,S	80
SCV	S	1	50	0	0	60	5	0	15	1	0	7		20
Siege Tank	L	2	150	100	1	150	30e/70es	0	37/75	7/12	3/5	10		50
Valkyrie	L	3	250	125	2	200	0	6es	64	6	1	8		50
Vulture	M	2	75	0	0	80	20c	0	30	5	2	8	S	30
Wraith	L	2	150	100	0	120	8	20e	30/22	5	1/2	7	S	60

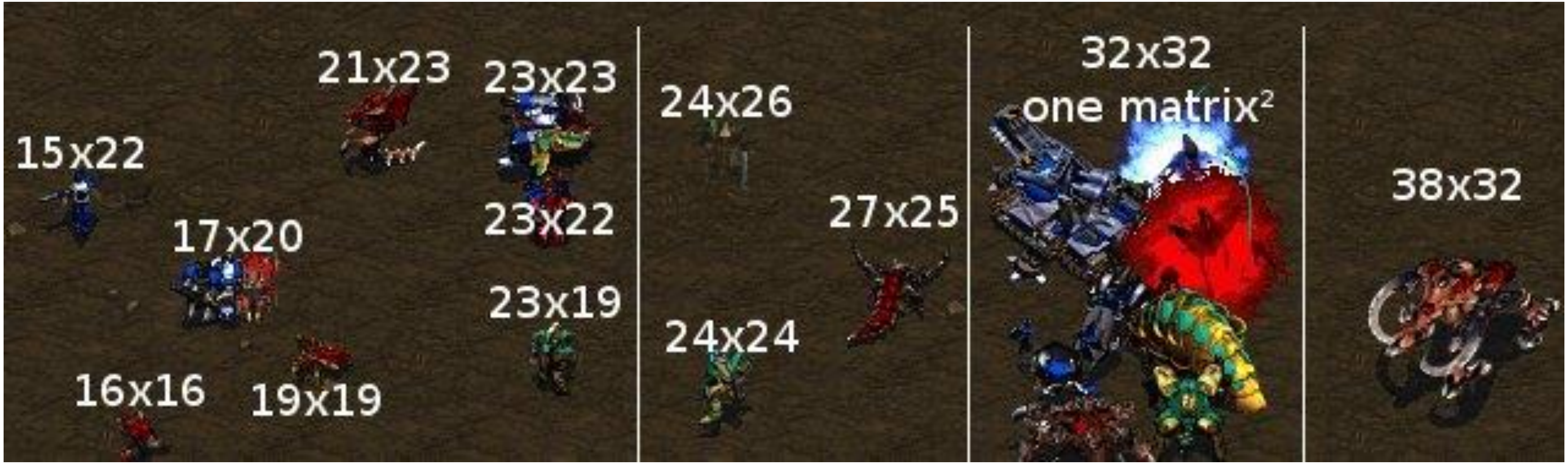
Zerg Unit Properties



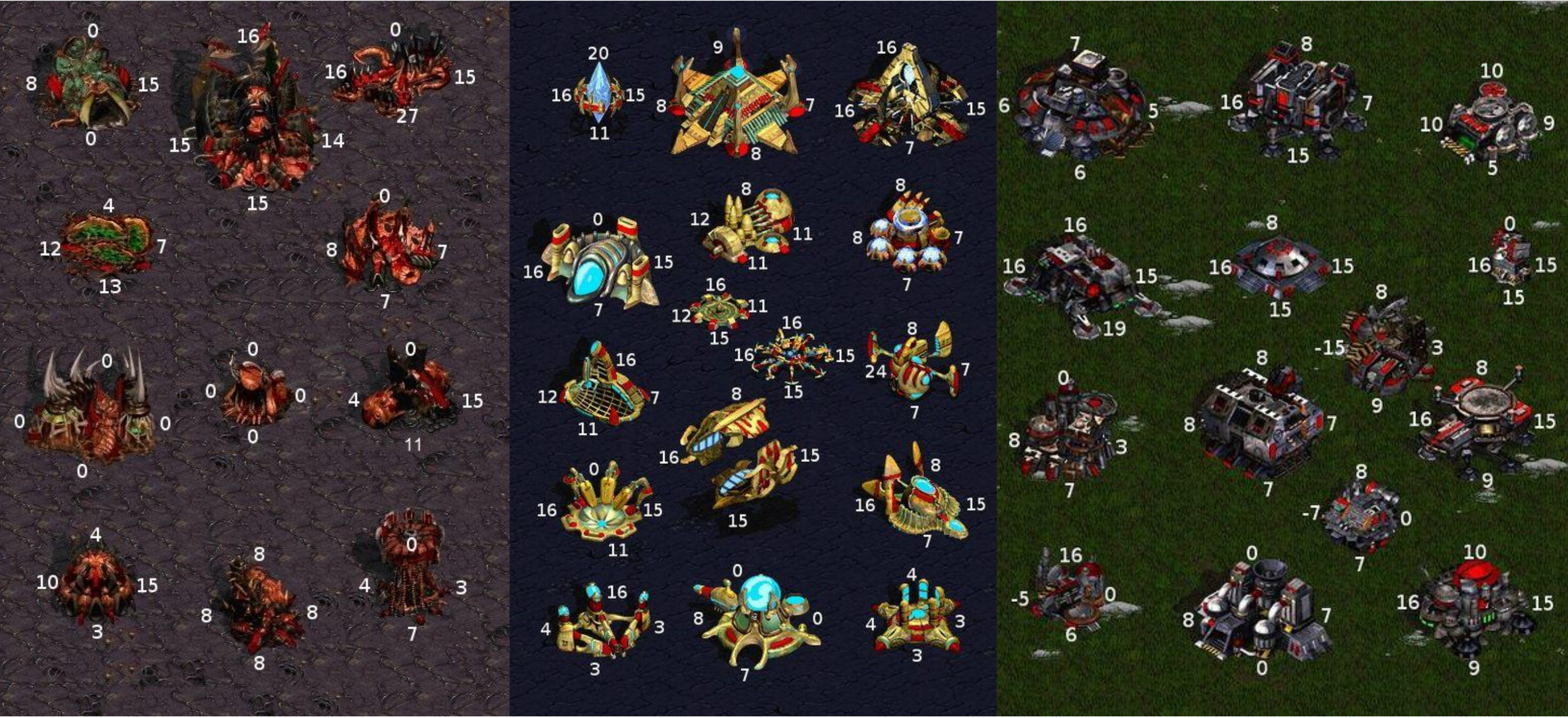
Unit	Size	Pop	Minerals	Gas	Armor	HP	Ground Attack	Air Attack	Cooldown	Range	Attack Mod	Sight	Notes	Build Time
Broodling	S	0	0	0	0	30	4	0	15	1	1	5	B	0
Cocoon	L	2	0	0	0	200	0	0		0	0	4	B	0
Defiler	M	2	50	150	1	80	0	0		0	0	10	B,S	50
Devourer	L	2	+150	+50	2	250	0	25e	100	6	2	10	B	40
Drone	S	1	50	0	0	40	5	0	22	1	0	7	B	20
Egg	L	0	0	0	10	200	0	0		0	0	4	B	0
Guardian	L	2	+50	+100	2	150	20	0	30	8	2	11	B	40
Hydralisk	M	1	75	25	0	80	10e	10e	15	4/5	1	6	B	28
Infested Terran	S	1	100	50	0	60	500es	0		1	0	5	B	40
Larva	S	0	0	0	10	25	0	0		0	0	4	B	20
Lurker	M	2	+50	+100	1	125	20s	0	37	6	2	8	B	40
Mutalisk	S	2	100	100	0	120	9	9	30	3	1	7	B	40
Overlord	L	0	100	0	0	200	0	0		0	0	9/11	B,D	40
Queen	M	2	100	100	0	120	0	0		0	0	10	B,S	50
Scourge	S	0.5	12	38	0	25	0	110		1	0	5	B	30
Spore Colony	L	0	+50	0	0	400	0	15	15	7	0	10	D	20
Sunken Colony	L	0	+50	0	2	300	40e	0	32	7	0	10		20
Ultralisk	L	4	200	200	1/3	400	20	0	15	1	3	7	B	60
Zergling	S	0.5	25	0	0	35	5	0	8/6	1	1	5	B	28

Starcraft Unit Sizes

- Starcraft unit size and movement in pixels



https://liquipedia.net/starcraft/List_of_Unit_and_Building_Sizes



https://liquipedia.net/starcraft/List_of_Unit_and_Building_Sizes

```
void importantClasses()
{
    // Starcraft unit structure, access all unit instance info
    BWAPI::Unit unit = nullptr;
    // Unit’s type, ie: Marine, Zergling, Nexus, etc
    BWAPI::UnitType type = unit->getType();
    // Starcraft game instance object, get all info from here
    int frame = BWAPI::Broodwar->getFrameCount()
    // Player object, access to all player info
    BWAPI::Player me = BWAPI::Broodwar->self();
    // Position object, where is a unit?
    BWAPI::Position p = unit->getPosition();
}
```

```
void unitExamples()
{
  for (auto unit : BWAPI::Broodwar->getAllUnits())
  {
    BWAPI::Position p = unit->getPosition();
    BWAPI::Player pl  = unit->getPlayer();
    bool myUnit       = (pl == BWAPI::Broodwar->self());
    int currentHP     = unit->getHitPoints()
    BWAPI::UnitType t = unit->getType();
    int groundDamage  = t.groundWeapon().damageAmount();
    bool isWorker     = t.isWorker();
    bool isProbe      = (t == BWAPI::UnitTypes::Protoss_Probe);
  }
} // BWAPI::Unit acts like a pointer, can be copied efficiently
```

Starcraft Resource Gathering

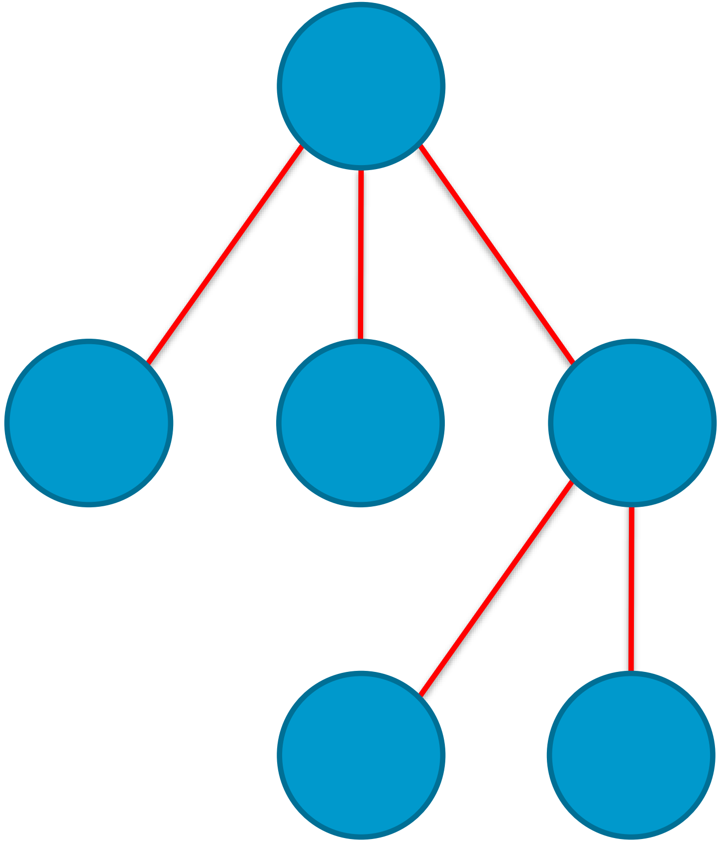
- In order to build units, you first need to gather resources with your workers
- This is easy for a human
- How to do it with a bot?
  1. Find closest mineral
  2. Find worker who is free
  3. Send worker to mine

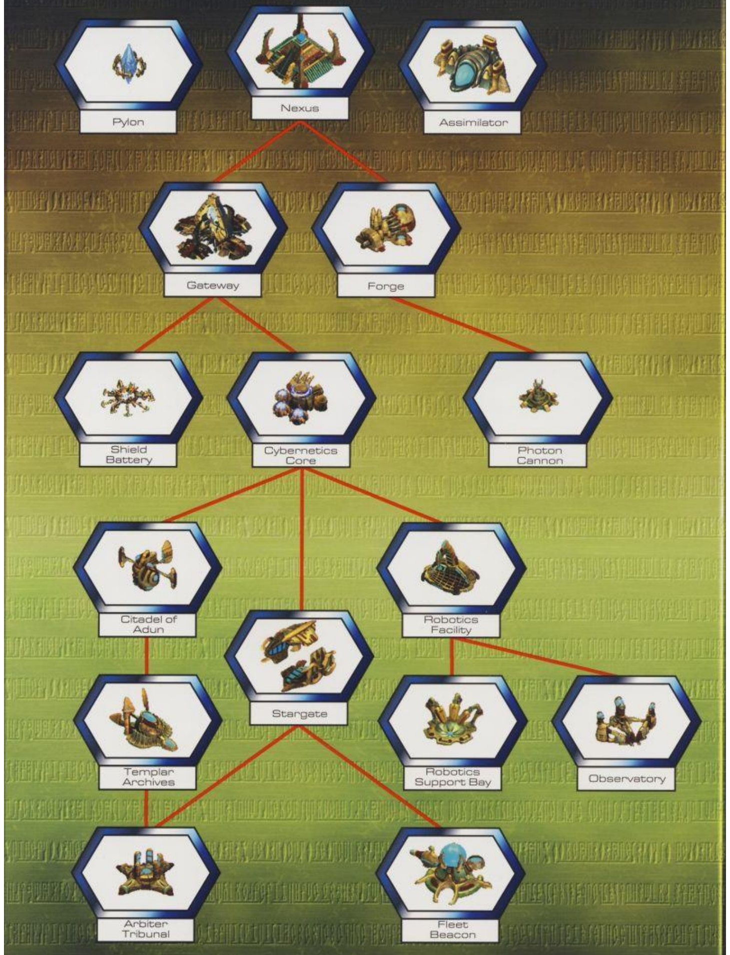
```
// send all idle workers to gather minerals
void gatherMinerals()
{
  for (auto unit : BWAPI::Broodwar->self()->getUnits())
  {
    if (!unit->getType().isWorker()) { continue; }
    if (!unit->isIdle())             { continue; }
    BWAPI::Unit mineral = getClosestMineral(unit);
    unit->rightClick(mineral);
  }
}
// unit will continue to mine until interrupted
// find closest mineral to a unit
BWAPI::Unit getClosestMineral(BWAPI::Unit myUnit)
{
  BWAPI::Unit closestMineral = nullptr;
  int minDist = std::numeric_limits<int>::max();
  for (auto unit : BWAPI::Broodwar->getNeutralUnits())
  {
    int dist = unit->getDistance(myUnit);
    if (dist < minDist)
    {
        minDist = dist;
        closestMineral = unit;
  }
  return closestMineral;
}
```

Army Composition

Starcraft Tech Tree

- Each building and unit in the game has a set of things required to build first
- Requirements: ‘tech’
- Tree listing: tech tree





Pylon

Nexus

Assimilator

Gateway

Forge

Shield Battery

Cybernetics Core

Photon Cannon

Citadel of Adun

Stargate

Robotics Facility

Templar Archives

Robotics Support Bay

Observatory

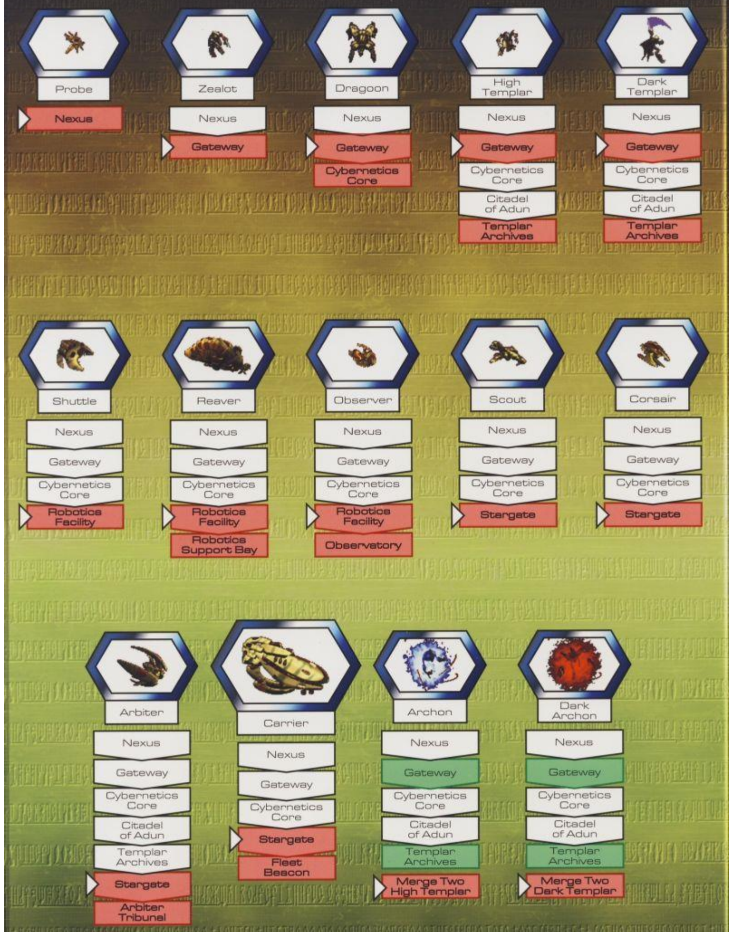
Arbiter Tribunal

Fleet Beacon

PROTOSS

BUILDING DEPENDENCIES

0429710



Probe
- Nexus

Zealot
- Nexus
- Gateway

Dragoon
- Nexus
- Gateway
- Cybernetics Core

High Templar
- Nexus
- Gateway
- Cybernetics Core
- Citadel of Adun
- Templar Archives

Dark Templar
- Nexus
- Gateway
- Cybernetics Core
- Citadel of Adun
- Templar Archives

Shuttle
- Nexus
- Gateway
- Cybernetics Core
- Robotics Facility

Reaver
- Nexus
- Gateway
- Cybernetics Core
- Robotics Facility
- Robotics Support Bay

Observer
- Nexus
- Gateway
- Cybernetics Core
- Robotics Facility
- Observatory

Scout
- Nexus
- Gateway
- Cybernetics Core
- Stargate

Corsair
- Nexus
- Gateway
- Cybernetics Core
- Stargate

Arbiter
- Nexus
- Gateway
- Cybernetics Core
- Citadel of Adun
- Templar Archives
- Stargate
- Arbiter Tribunal

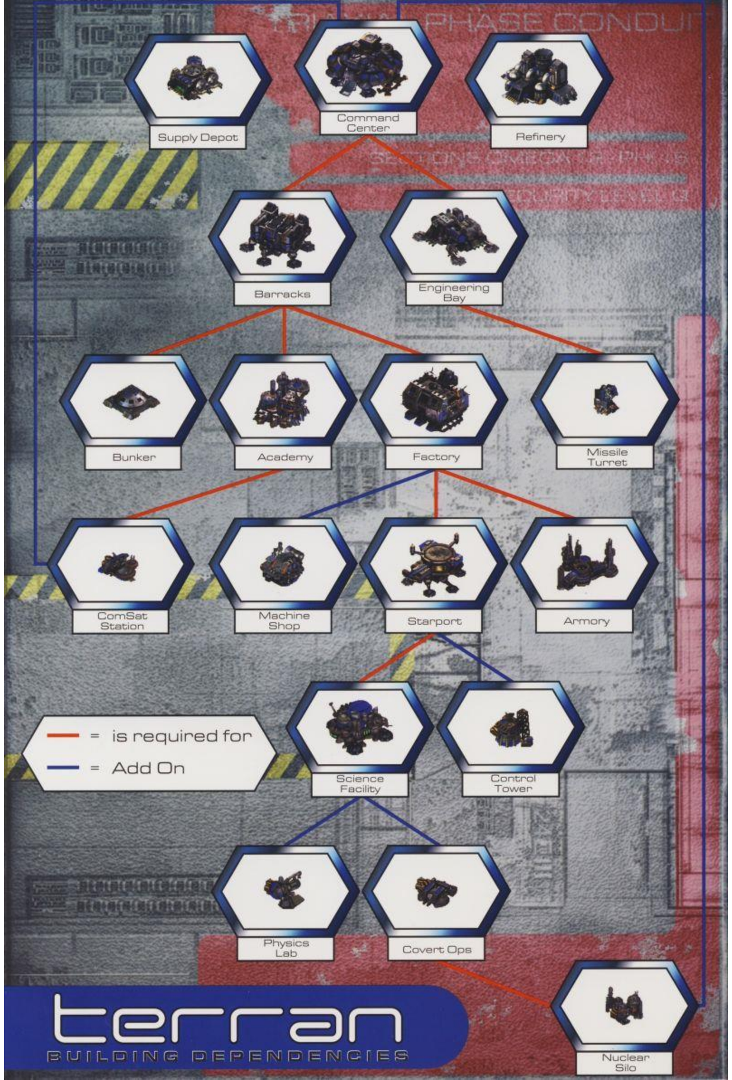
Carrier
- Nexus
- Gateway
- Cybernetics Core
- Stargate
- Fleet Beacon

Archon
- Nexus
- Gateway
- Cybernetics Core
- Citadel of Adun
- Templar Archives
- Merge Two High Templar

Dark Archon
- Nexus
- Gateway
- Cybernetics Core
- Citadel of Adun
- Templar Archives
- Merge Two Dark Templar

PROTOSS

UNIT DEPENDENCIES

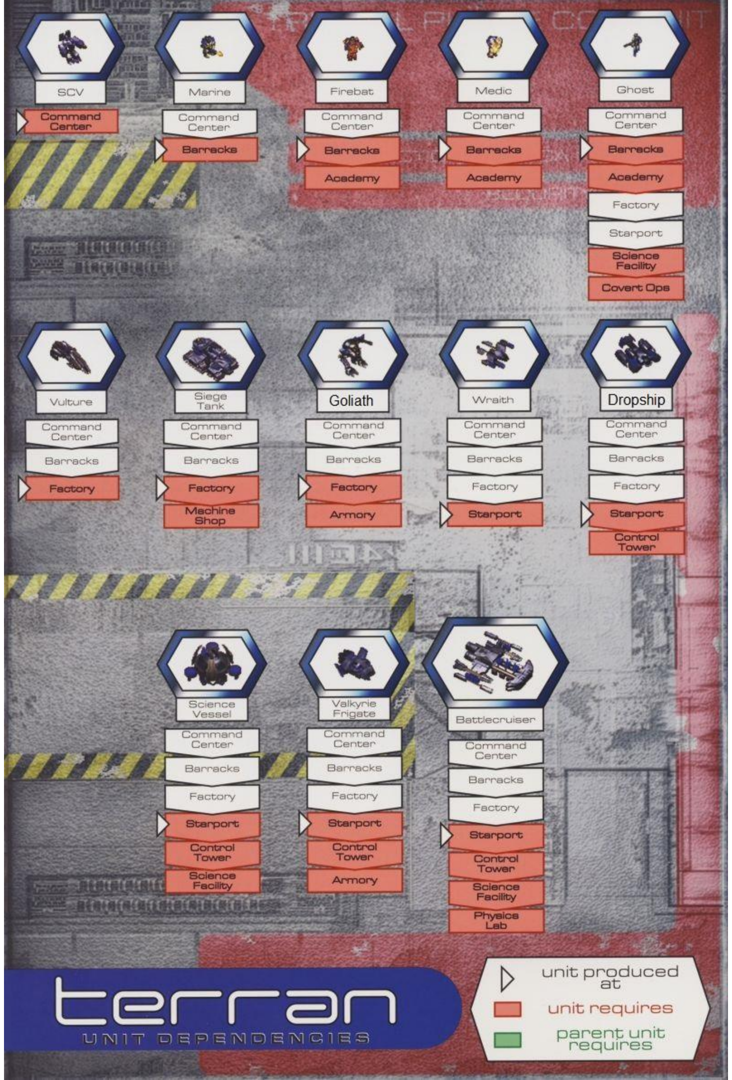


🟥 = is required for

🟦 = Add On

terran

BUILDING DEPENDENCIES



SCV
- ▷ 🟥 Command Center

Marine
- Command Center
- ▷ 🟥 Barracks

Firebat
- Command Center
- ▷ 🟥 Barracks
- 🟥 Academy

Medic
- Command Center
- ▷ 🟥 Barracks
- 🟥 Academy

Ghost
- Command Center
- ▷ 🟥 Barracks
- 🟥 Academy
- Factory
- Starport
- 🟥 Science Facility
- 🟥 Covert Ops

Vulture
- Command Center
- Barracks
- ▷ 🟥 Factory

Siege Tank
- Command Center
- Barracks
- ▷ 🟥 Factory
- 🟥 Machine Shop

Goliath
- Command Center
- Barracks
- ▷ 🟥 Factory
- 🟥 Armory

Wraith
- Command Center
- Barracks
- Factory
- ▷ 🟥 Starport

Dropship
- Command Center
- Barracks
- Factory
- ▷ 🟥 Starport
- 🟥 Control Tower

Science Vessel
- Command Center
- Barracks
- Factory
- ▷ 🟥 Starport
- 🟥 Control Tower
- 🟥 Science Facility

Valkyrie Frigate
- Command Center
- Barracks
- Factory
- ▷ 🟥 Starport
- 🟥 Control Tower
- 🟥 Armory

Battlecruiser
- Command Center
- Barracks
- Factory
- ▷ 🟥 Starport
- 🟥 Control Tower
- 🟥 Science Facility
- 🟥 Physics Lab

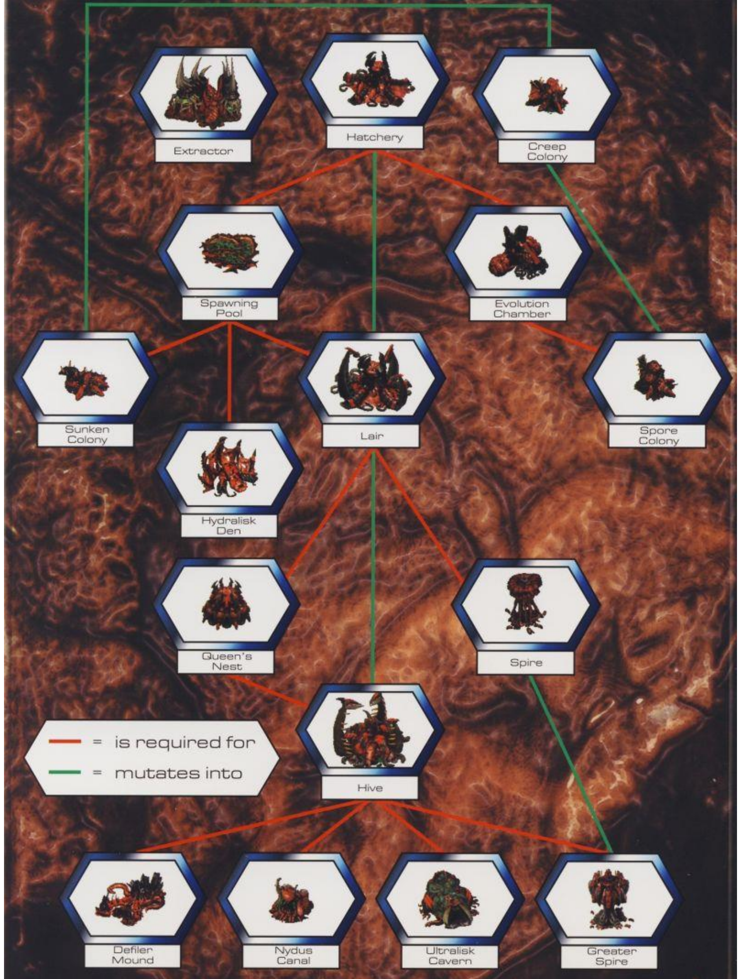
terran

UNIT DEPENDENCIES

▷ unit produced at

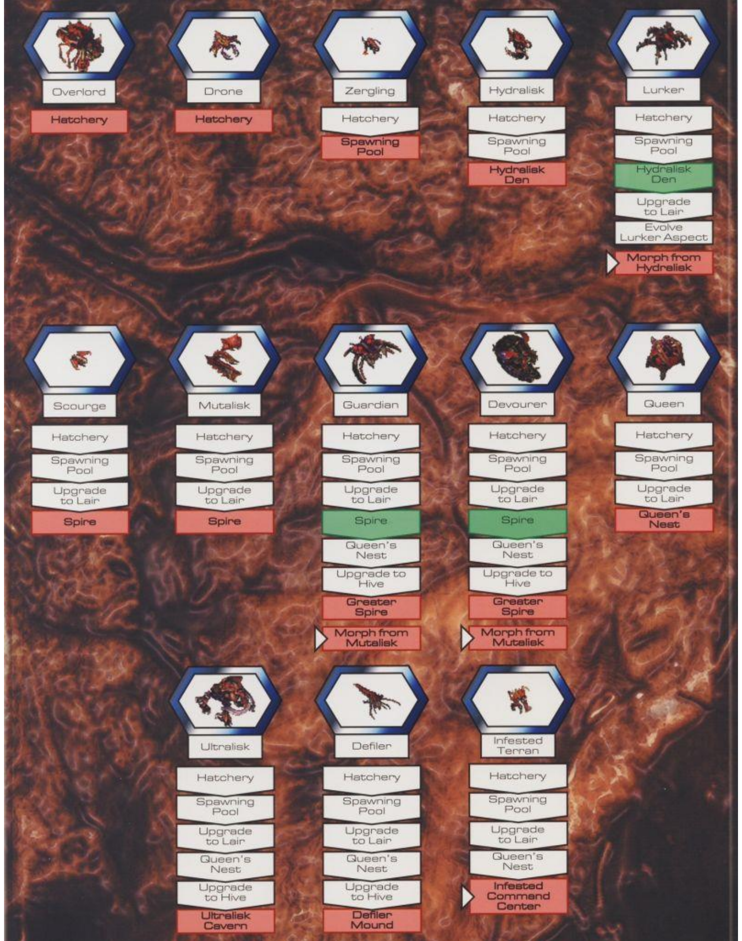
🟥 unit requires

🟩 parent unit requires



zerg

BUILDING DEPENDENCIES



Overlord
- Hatchery

Drone
- Hatchery

Zergling
- Hatchery
- Spawning Pool

Hydralisk
- Hatchery
- Spawning Pool
- Hydralisk Den

Lurker
- Hatchery
- Spawning Pool
- Hydralisk Den
- Upgrade to Lair
- Evolve Lurker Aspect
- Morph from Hydralisk

Scourge
- Hatchery
- Spawning Pool
- Upgrade to Lair
- Spire

Mutalisk
- Hatchery
- Spawning Pool
- Upgrade to Lair
- Spire

Guardian
- Hatchery
- Spawning Pool
- Upgrade to Lair
- Spire
- Queen's Nest
- Upgrade to Hive
- Greater Spire
- Morph from Mutalisk

Devourer
- Hatchery
- Spawning Pool
- Upgrade to Lair
- Spire
- Queen's Nest
- Upgrade to Hive
- Greater Spire
- Morph from Mutalisk

Queen
- Hatchery
- Spawning Pool
- Upgrade to Lair
- Queen's Nest

Ultralisk
- Hatchery
- Spawning Pool
- Upgrade to Lair
- Queen's Nest
- Upgrade to Hive
- Ultralisk Cavern

Defiler
- Hatchery
- Spawning Pool
- Upgrade to Lair
- Queen's Nest
- Upgrade to Hive
- Defiler Mound

Infested Terran
- Hatchery
- Spawning Pool
- Upgrade to Lair
- Queen's Nest
- Infested Command Center

zerg

UNIT DEPENDENCIES

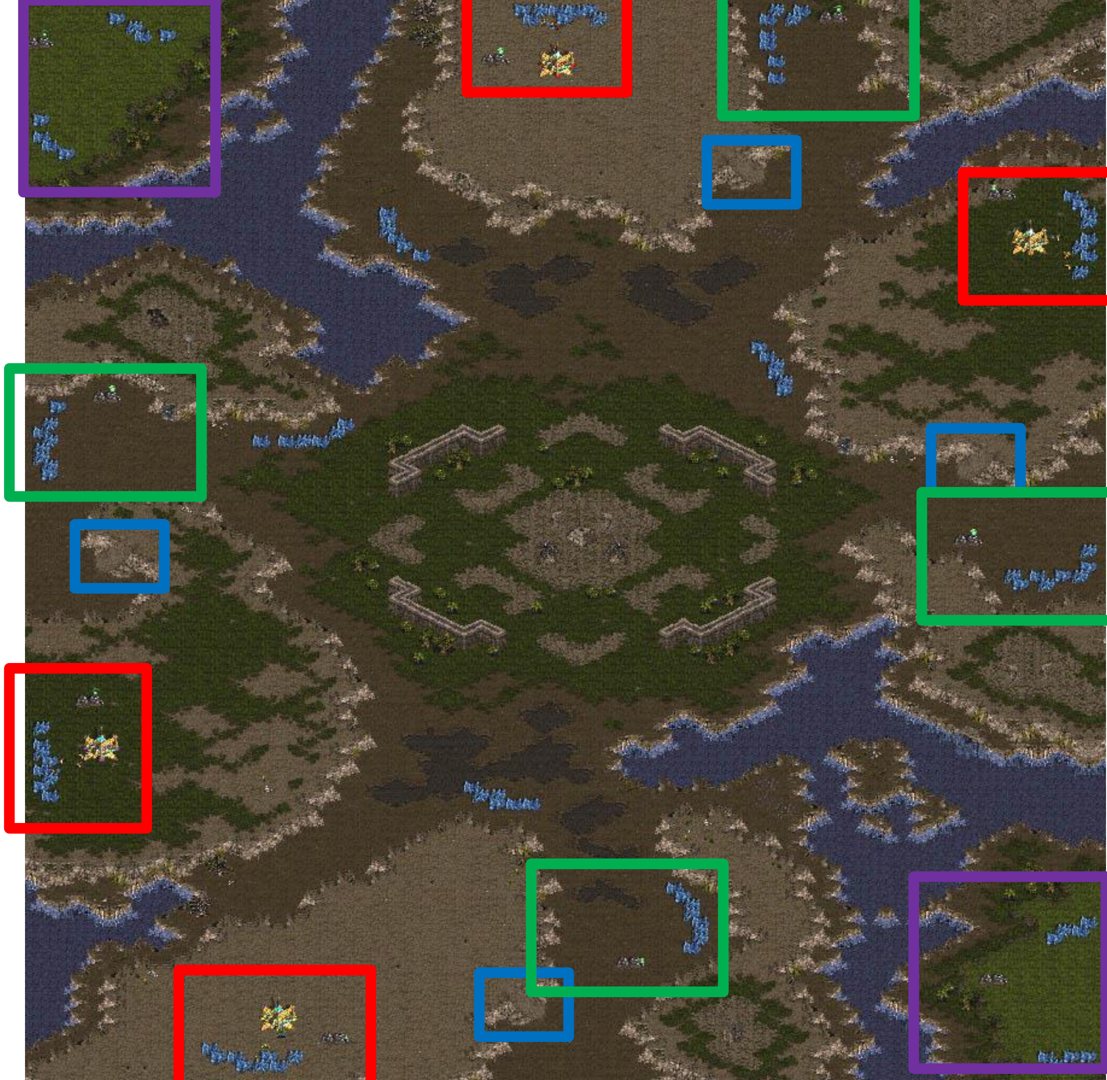
Starcraft Map

Start Locations

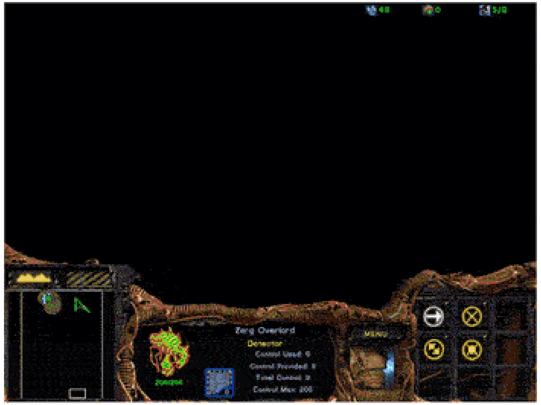
Choke Point

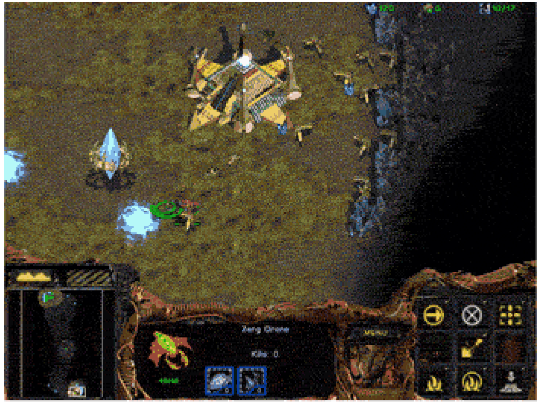
Expansions

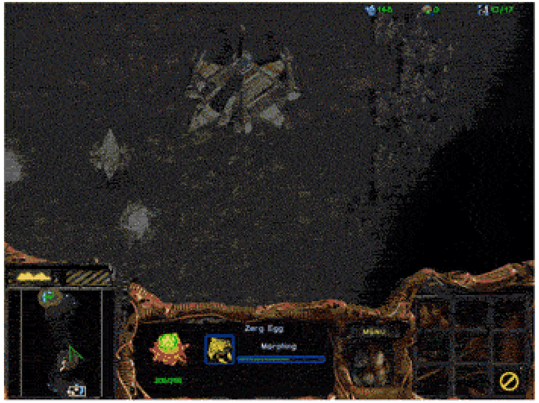
Islands



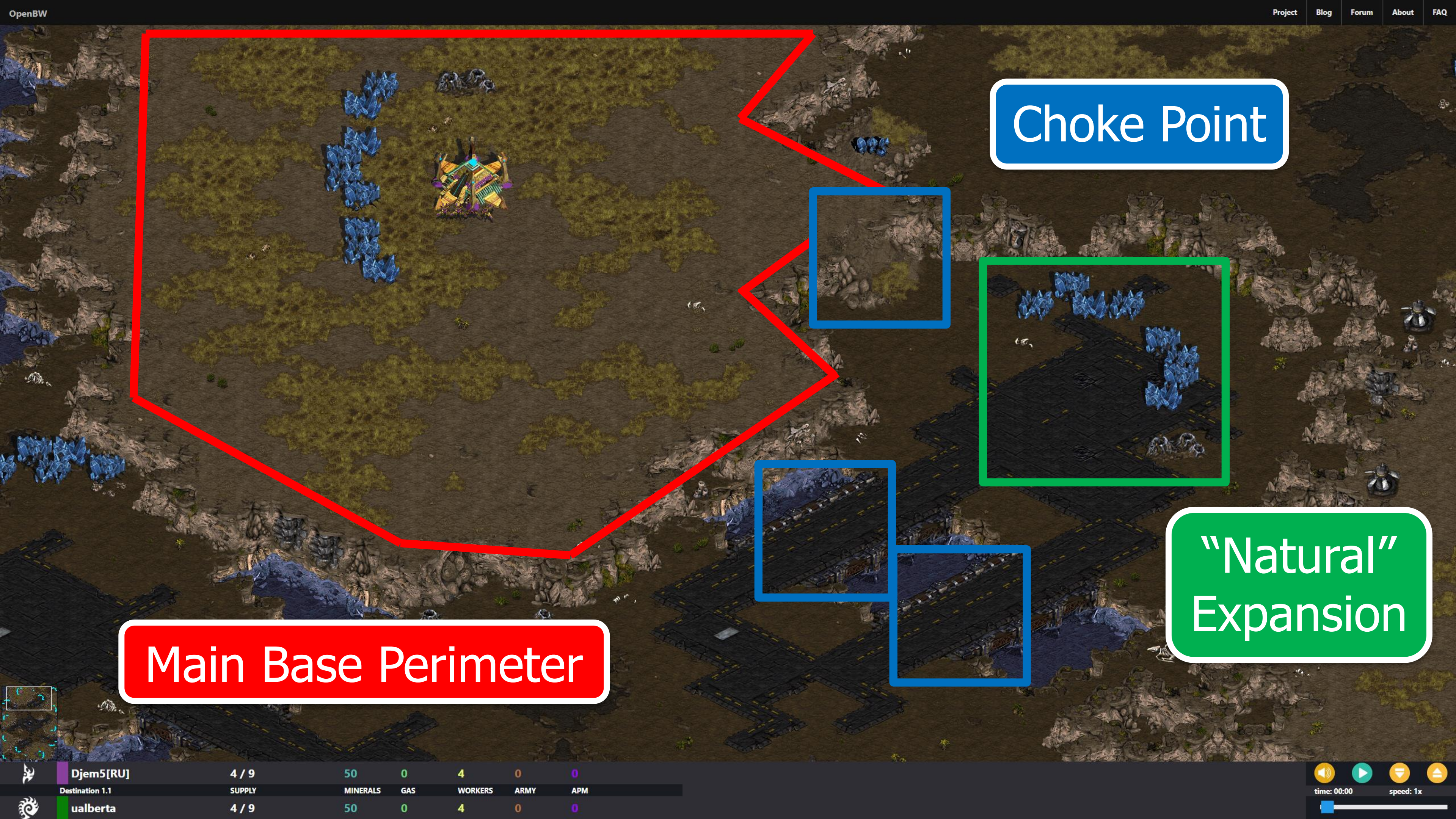
Starcraft Map – Fog of War







Imperfect Information

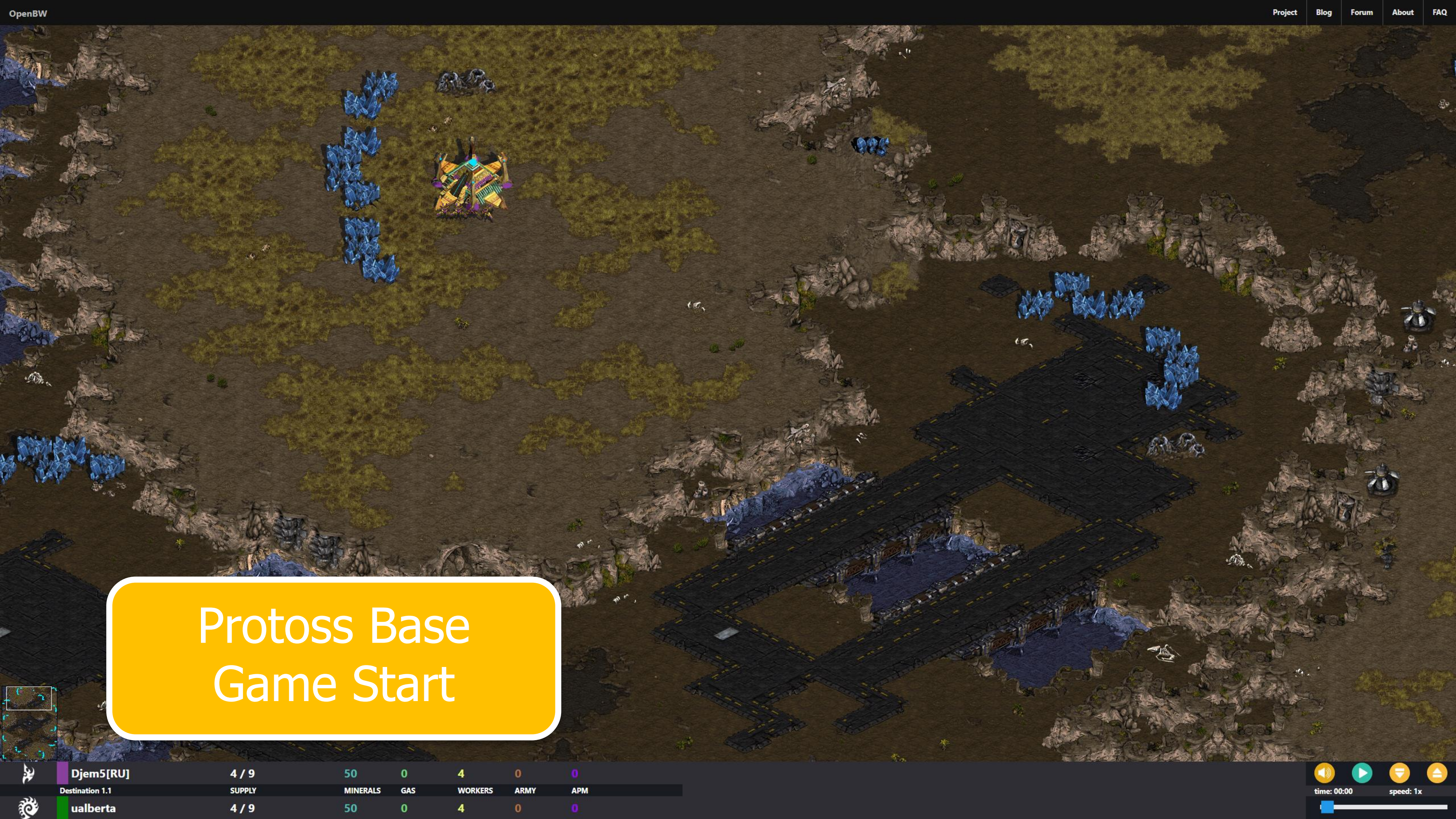


Choke Point

“Natural” Expansion

Main Base Perimeter

	SUPPLY	MINERALS	GAS	WORKERS	ARMY	APM
Djem5[RU]	4 / 9	50	0	4	0	0
Destination 1.1						
ualberta	4 / 9	50	0	4	0	0

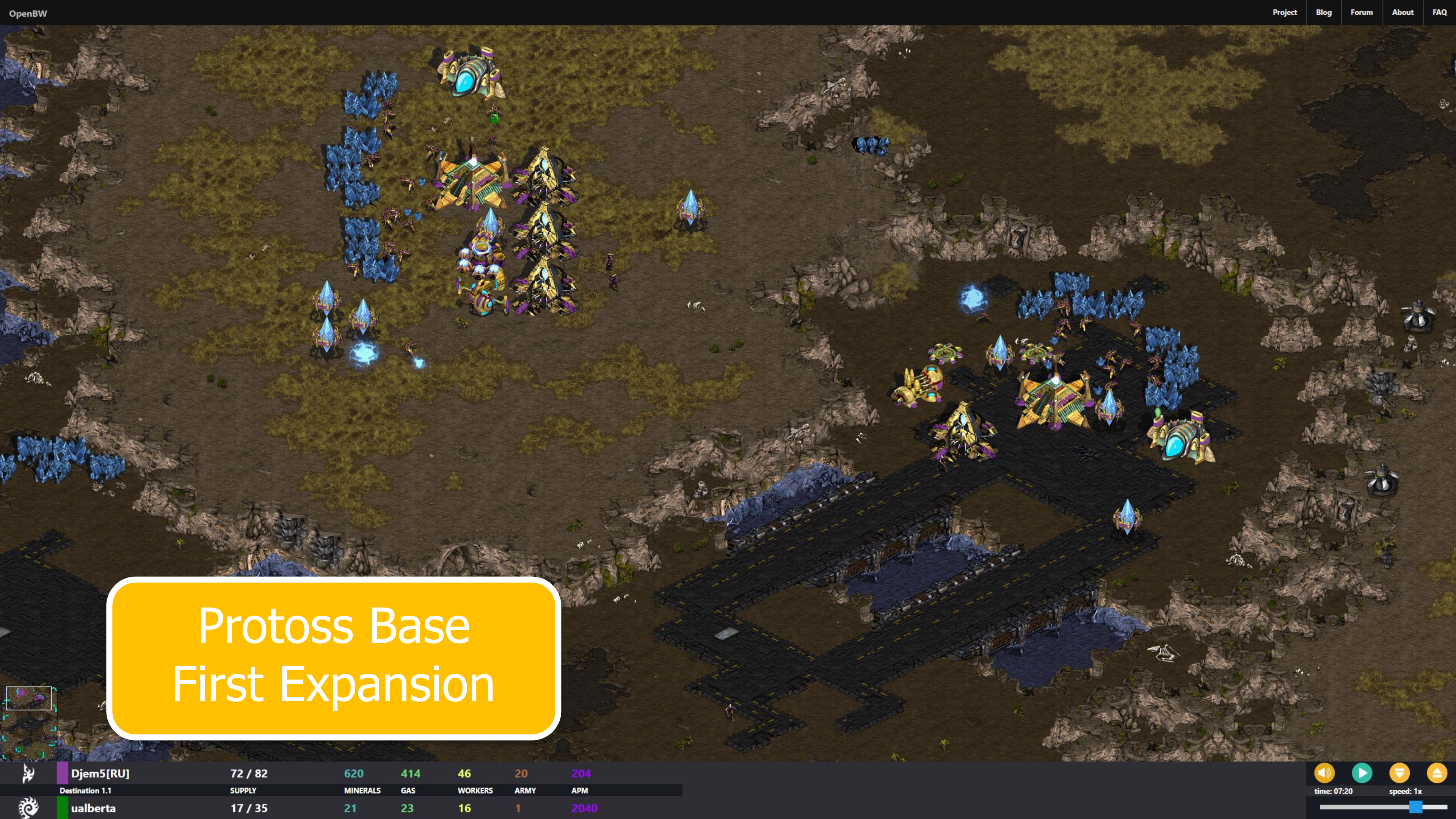


Protoss Base
Game Start

Destination 1.1	SUPPLY	MINERALS	GAS	WORKERS	ARMY	APM
Djem5[RU]	4 / 9	50	0	4	0	0
ualberta	4 / 9	50	0	4	0	0

time: 00:00

speed: 1x

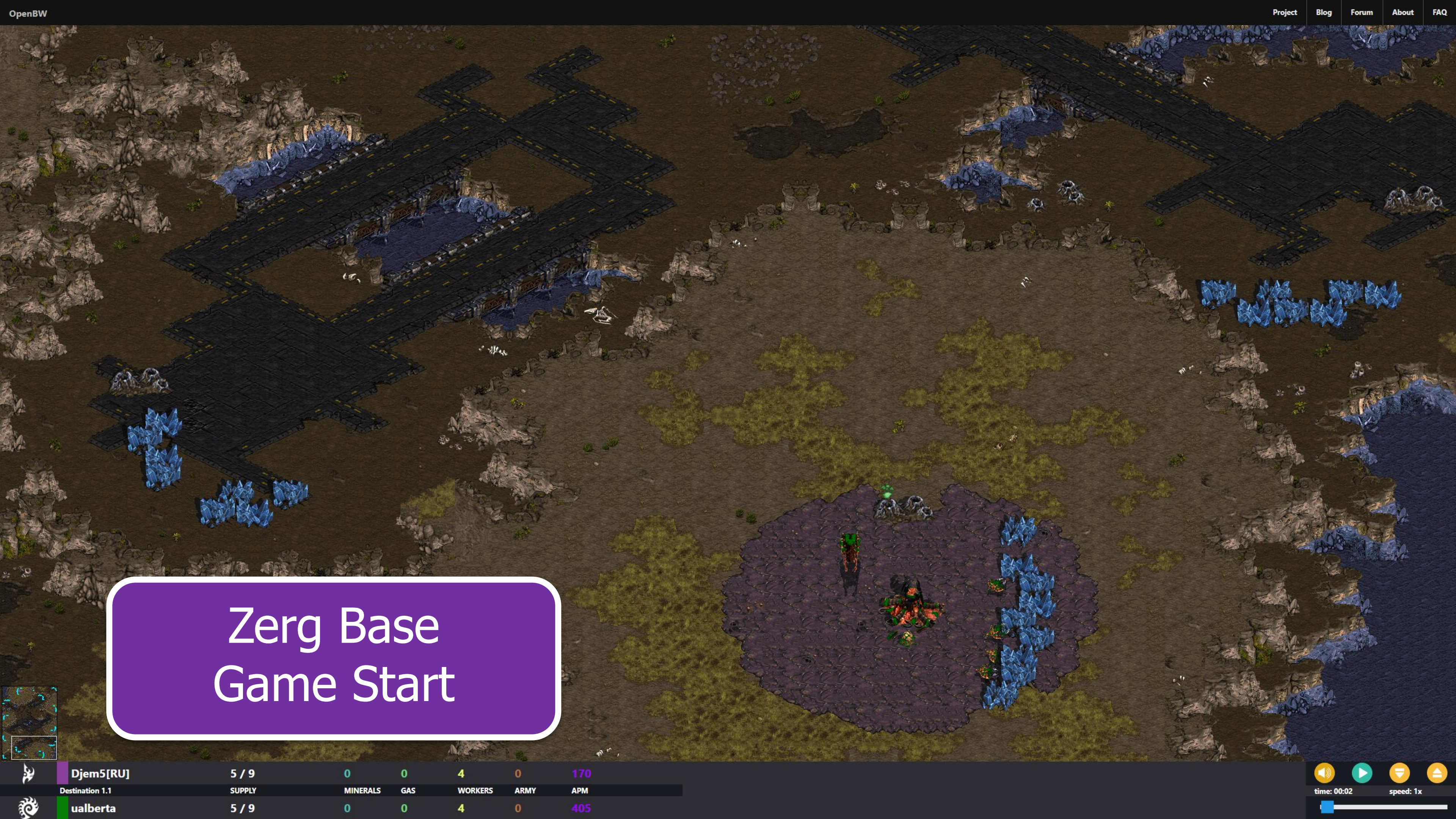


Protoss Base
First Expansion

Djem5[RU]	72 / 82	620	414	46	20	204
Destination 1.1	SUPPLY	MINERALS	GAS	WORKERS	ARMY	APM
ualberta	17 / 35	21	23	16	1	2040

time: 07:20

speed: 1x



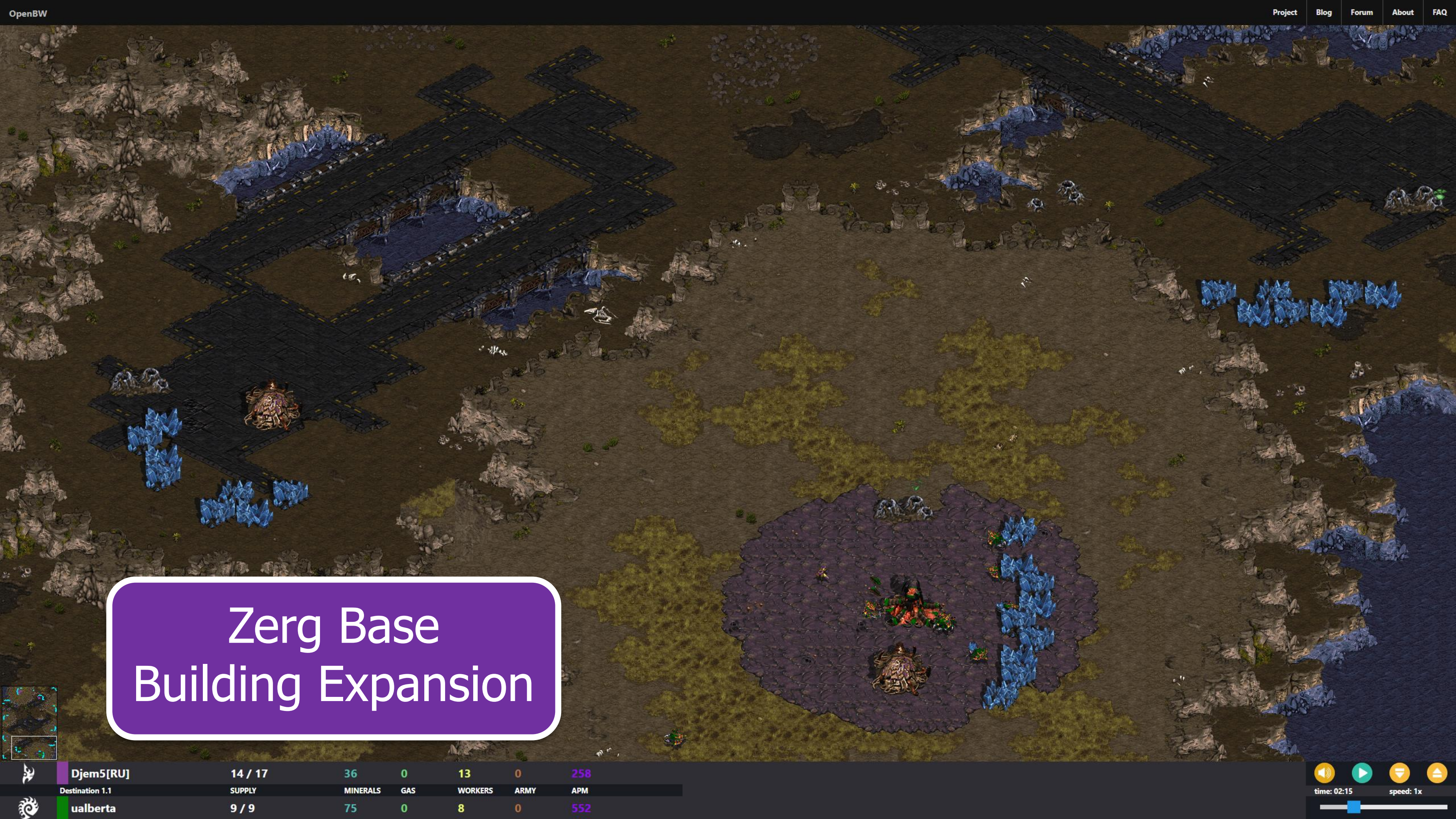
Zerg Base
Game Start

Djem5[RU]	5 / 9	0	0	4	0	170
Destination 1.1	SUPPLY	MINERALS	GAS	WORKERS	ARMY	APM
ualberta	5 / 9	0	0	4	0	405

time: 00:02

speed: 1x

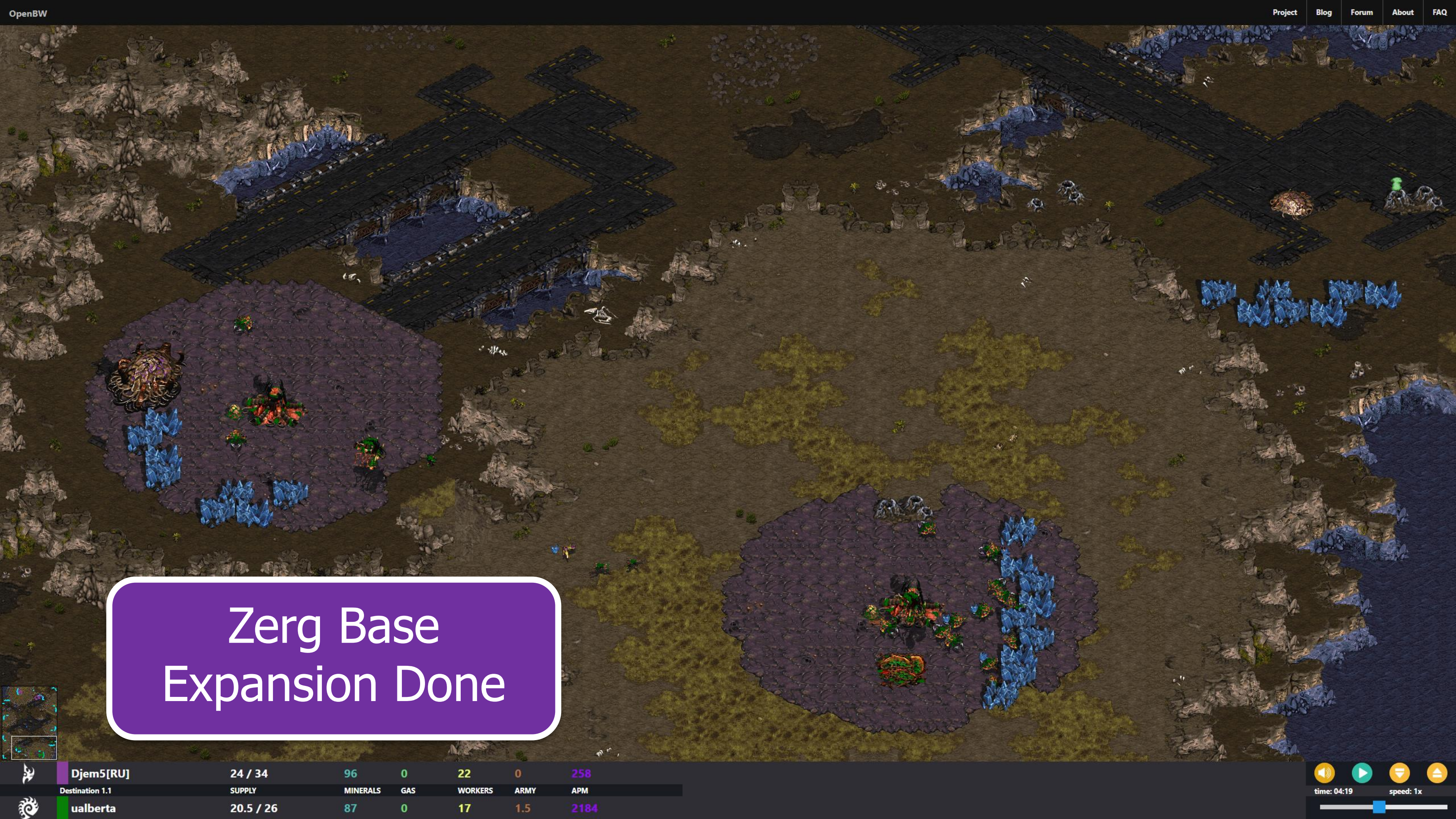
Zerg Base
Building Expansion



Djem5[RU]	14 / 17	36	0	13	0	258
Destination 1.1	SUPPLY	MINERALS	GAS	WORKERS	ARMY	APM
ualberta	9 / 9	75	0	8	0	552

time: 02:15

speed: 1x



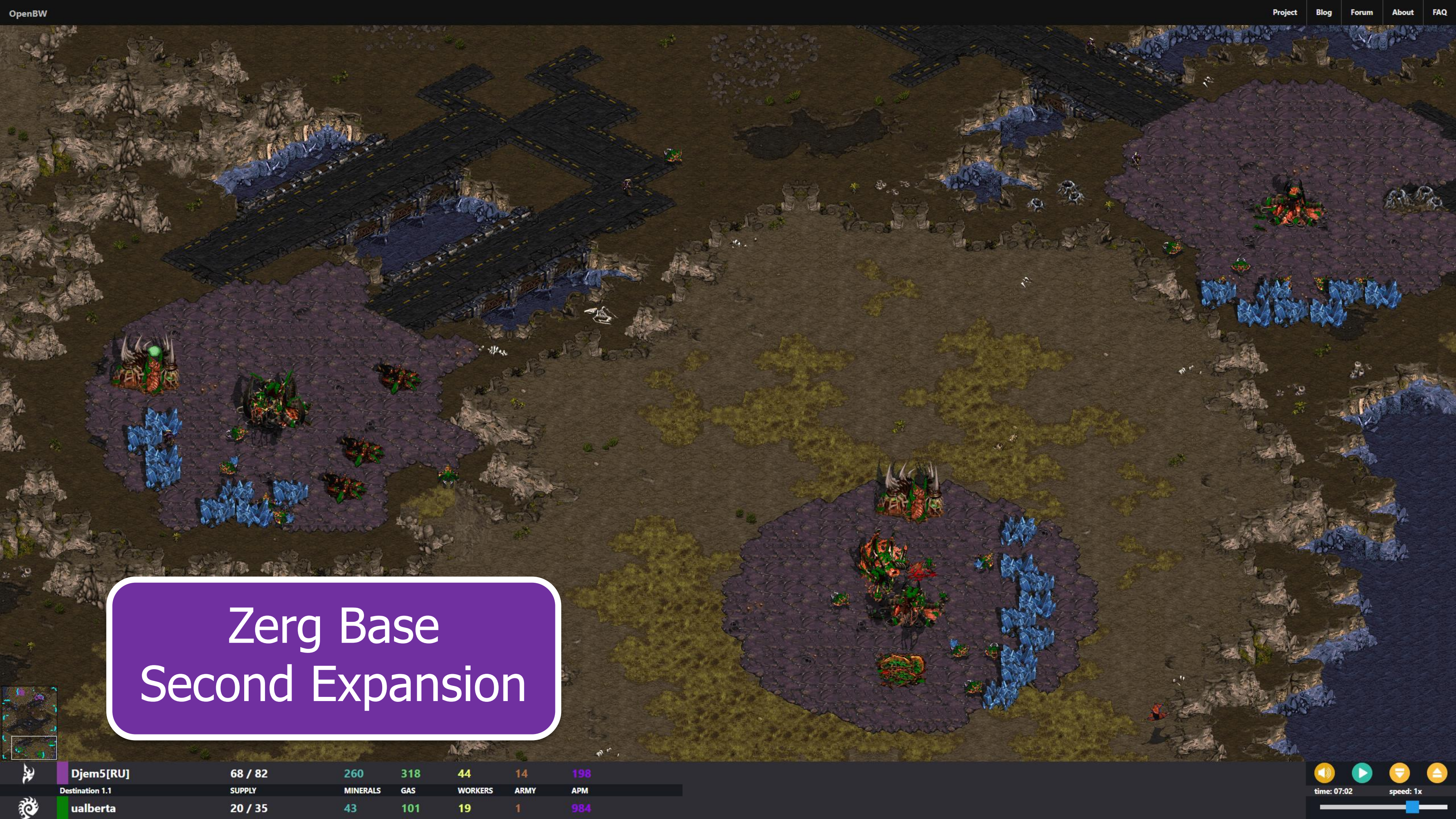
Zerg Base Expansion Done

Destination 1.1

	SUPPLY	MINERALS	GAS	WORKERS	ARMY	APM
Djem5[RU]	24 / 34	96	0	22	0	258
ualberta	20.5 / 26	87	0	17	1.5	2184

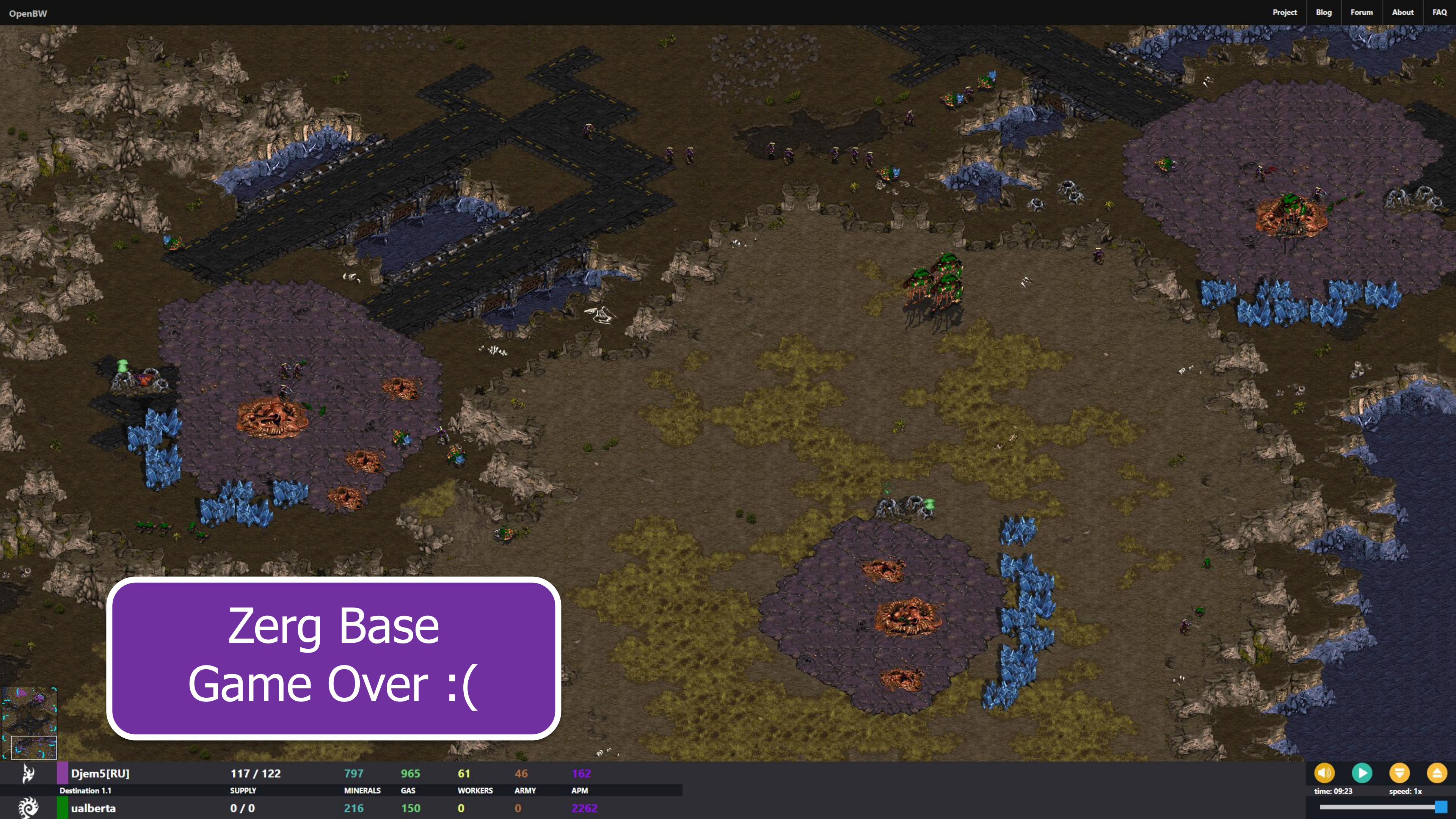
time: 04:19

speed: 1x



Zerg Base
Second Expansion

Djem5[RU]	68 / 82	260	318	44	14	198
Destination 1.1	SUPPLY	MINERALS	GAS	WORKERS	ARMY	APM
ualberta	20 / 35	43	101	19	1	984



Zerg Base
Game Over :(

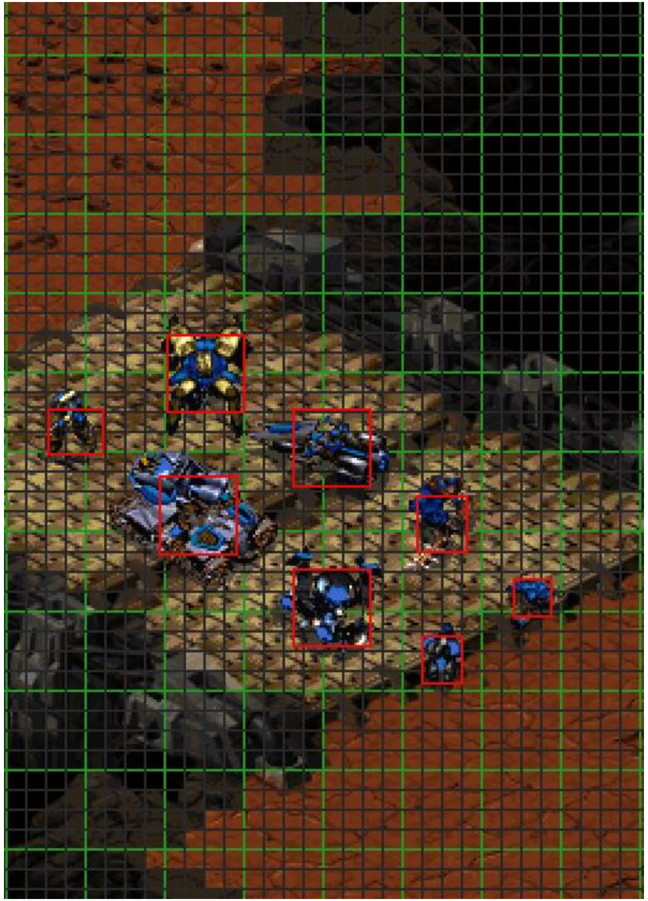
Djem5[RU]	117 / 122	797	965	61	46	162
Destination 1.1	SUPPLY	MINERALS	GAS	WORKERS	ARMY	APM
ualberta	0 / 0	216	150	0	0	2262

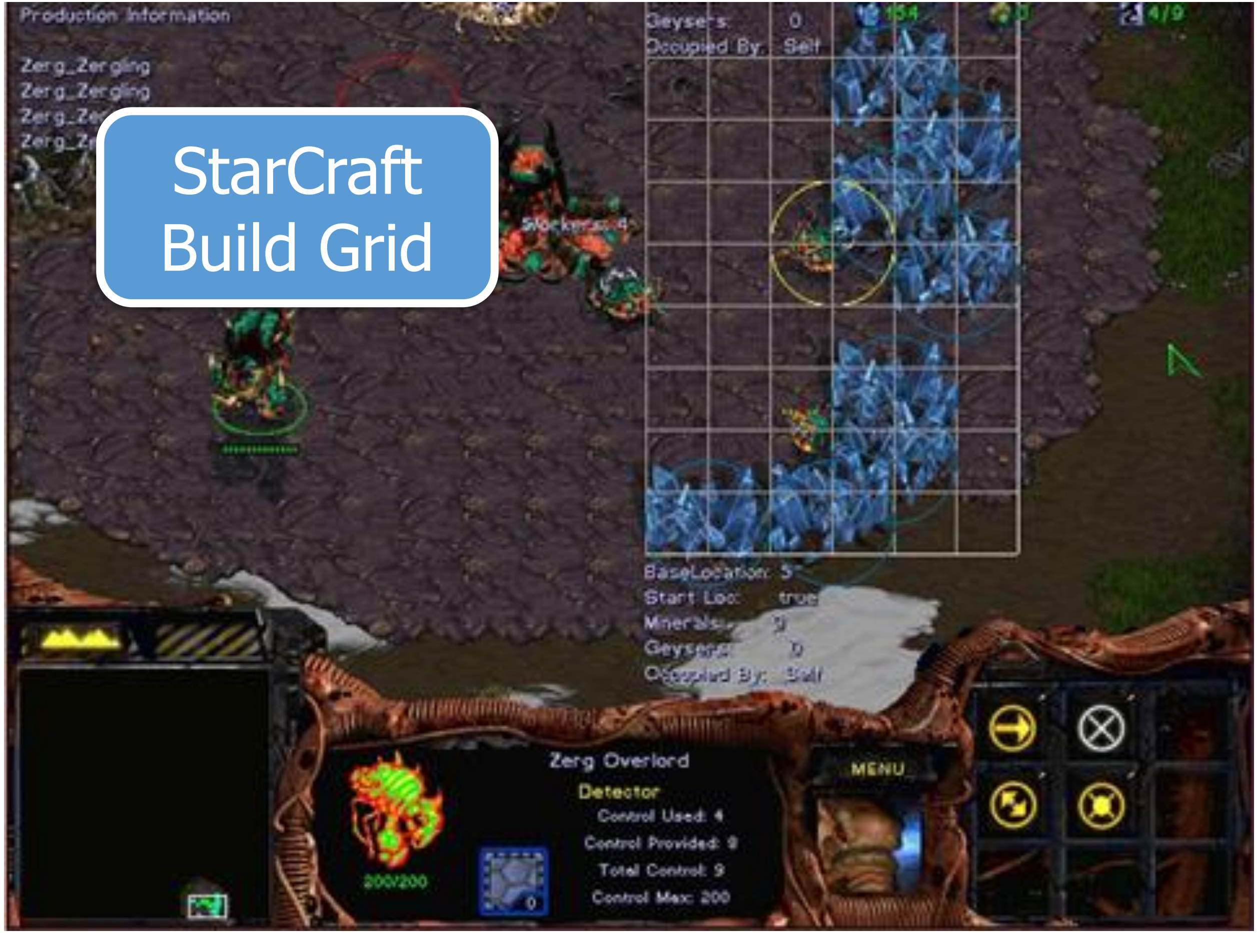
Starcraft Grid System

- Starcraft maps work on a Grid system
- Different types of grids, each with their own level of precision and task
- Maps are drawn in-game with textures that are applied to the underlying grid
- Grid are not visible in-game, but all game logic operates at one of these levels

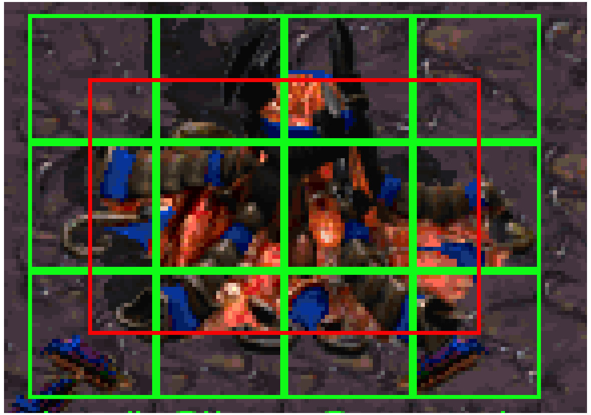
StarCraft Grids

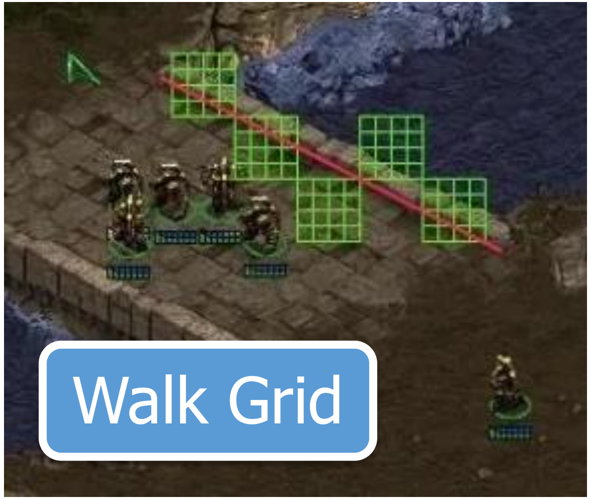
- Pixel Level (1x1 pixel)
    - Units move in pixel increments
    - BWAPI::Position
- Walk Tile (8x8 pixels)
    - Map 'walkability' Boolean grid
    - Units can't overlap 'false' tiles
    - BWAPI::WalkPosition (rarely used)
- Build Tile (32x32 pixels)
    - Building placed on w*h rectangle
    - Can't place on unwalkable tile
    - BWAPI::TilePosition



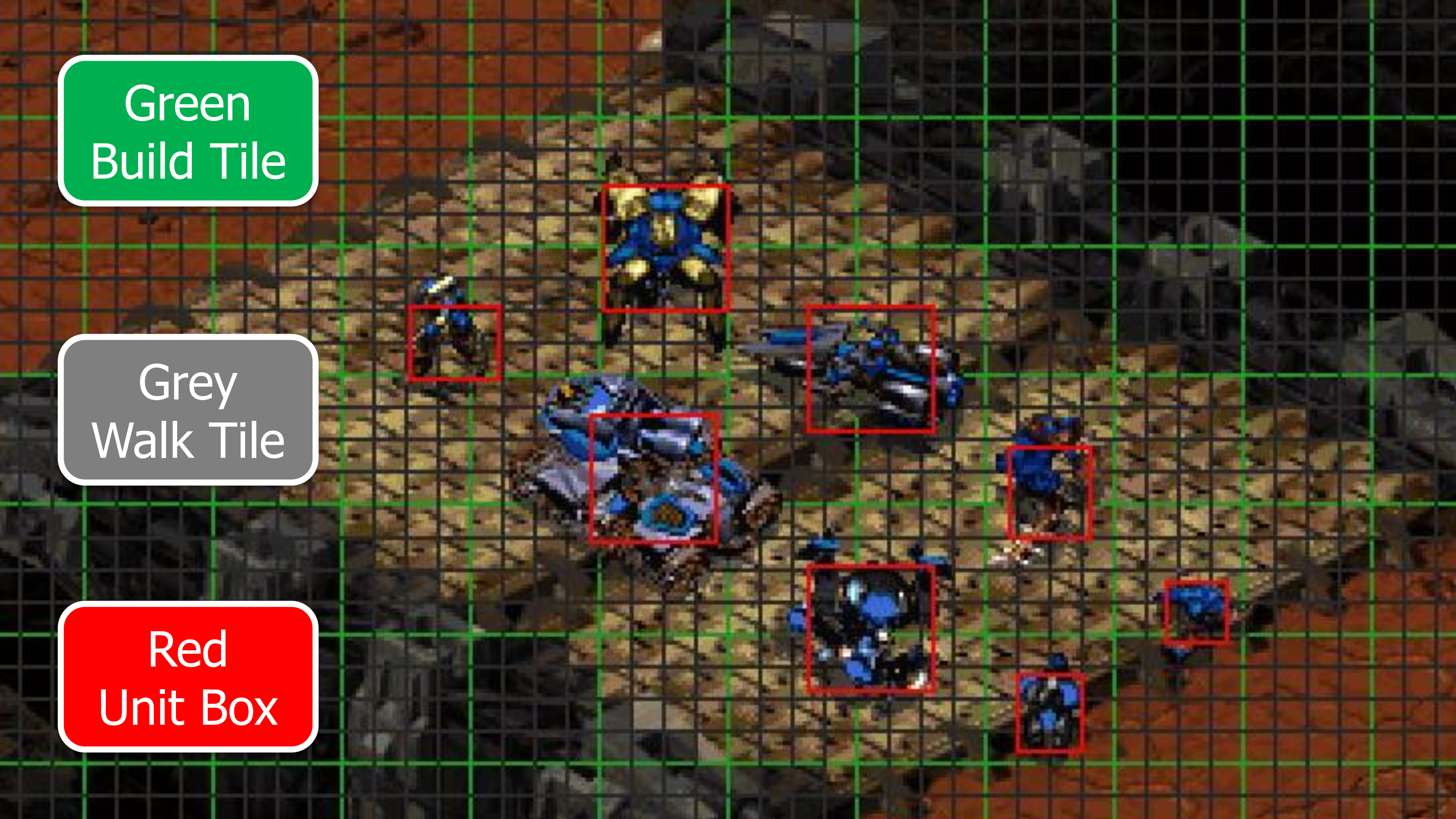


StarCraft Build Grid





Walk Grid

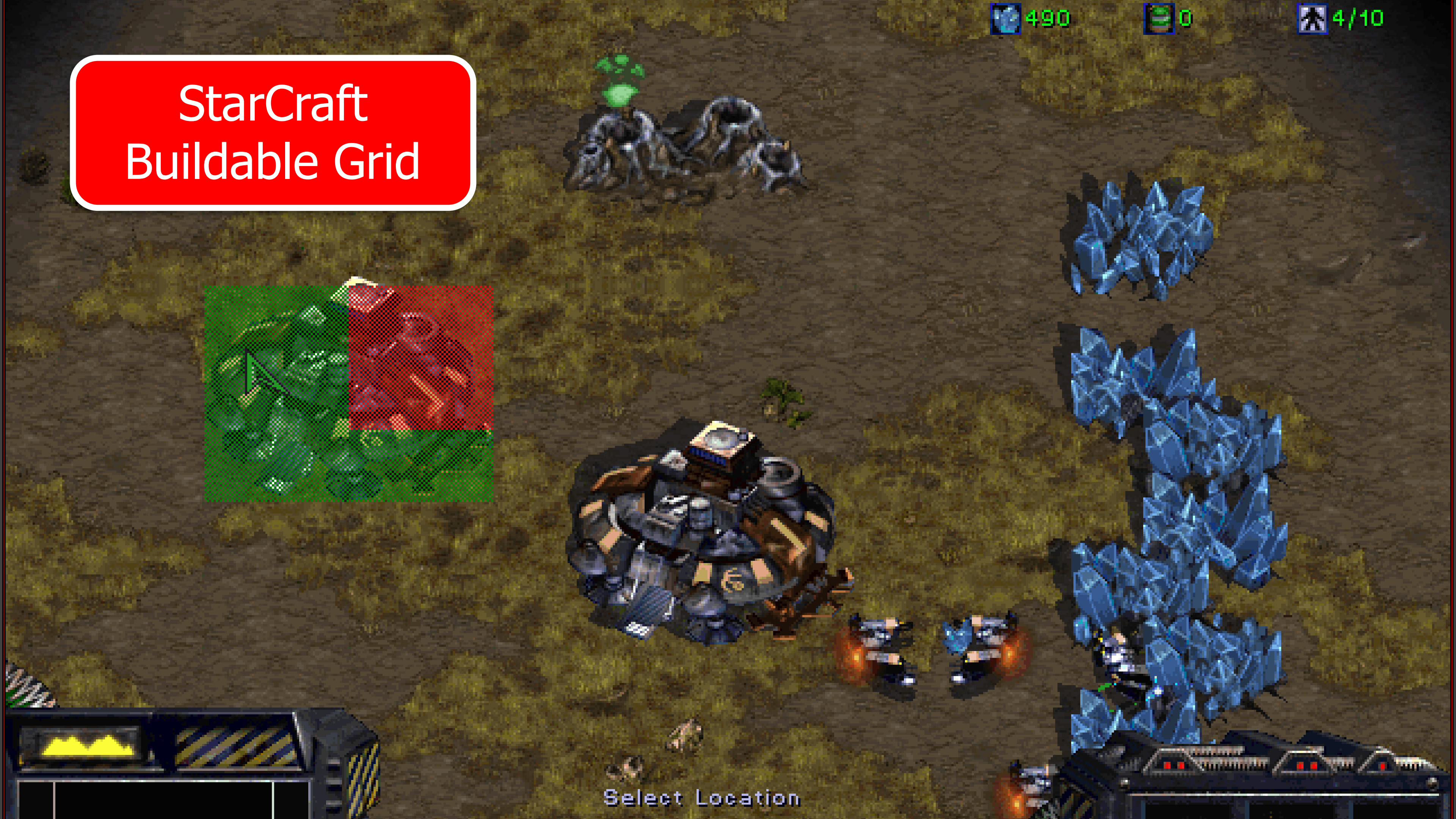


Green Build Tile

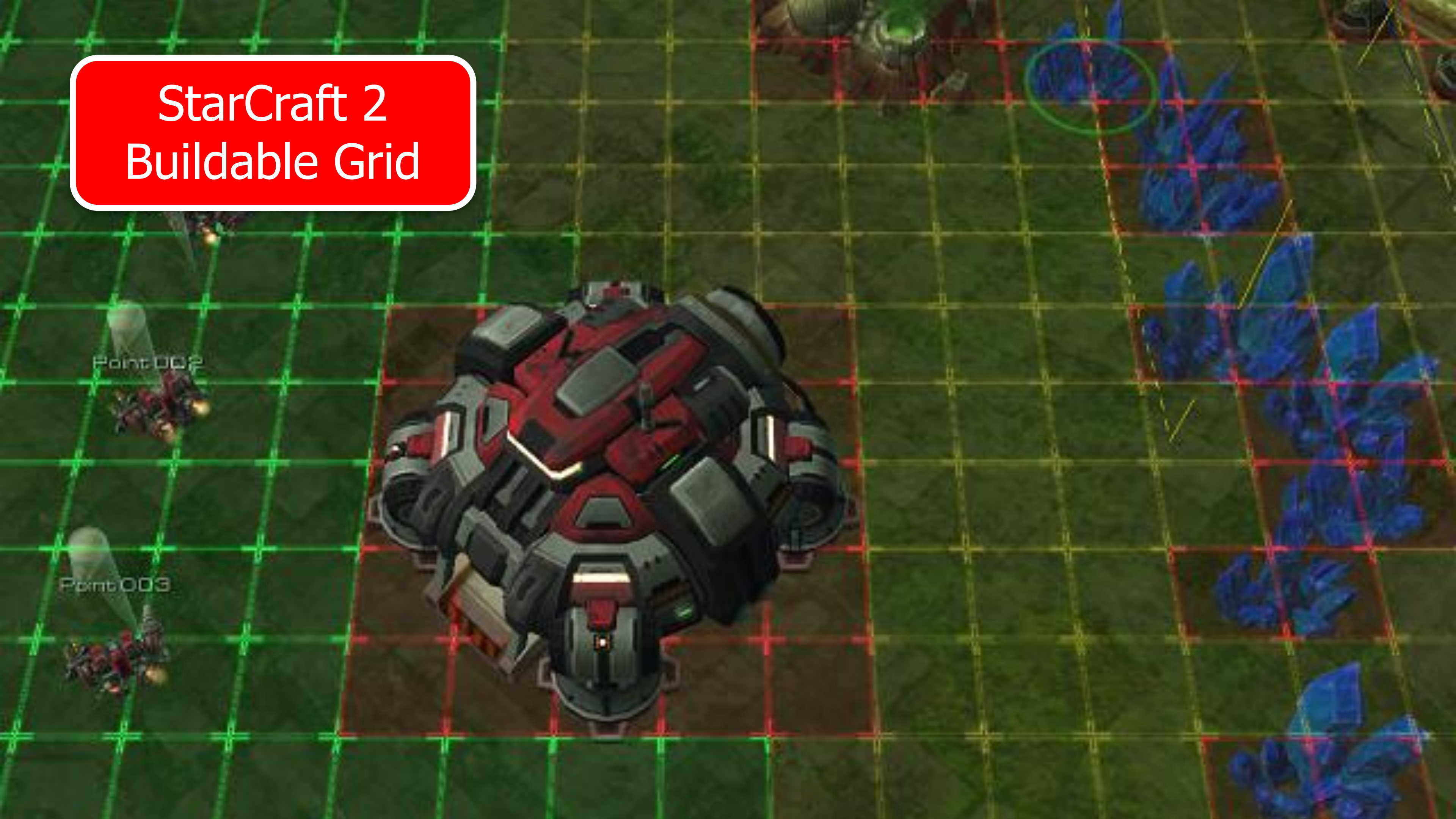
Grey Walk Tile

Red Unit Box

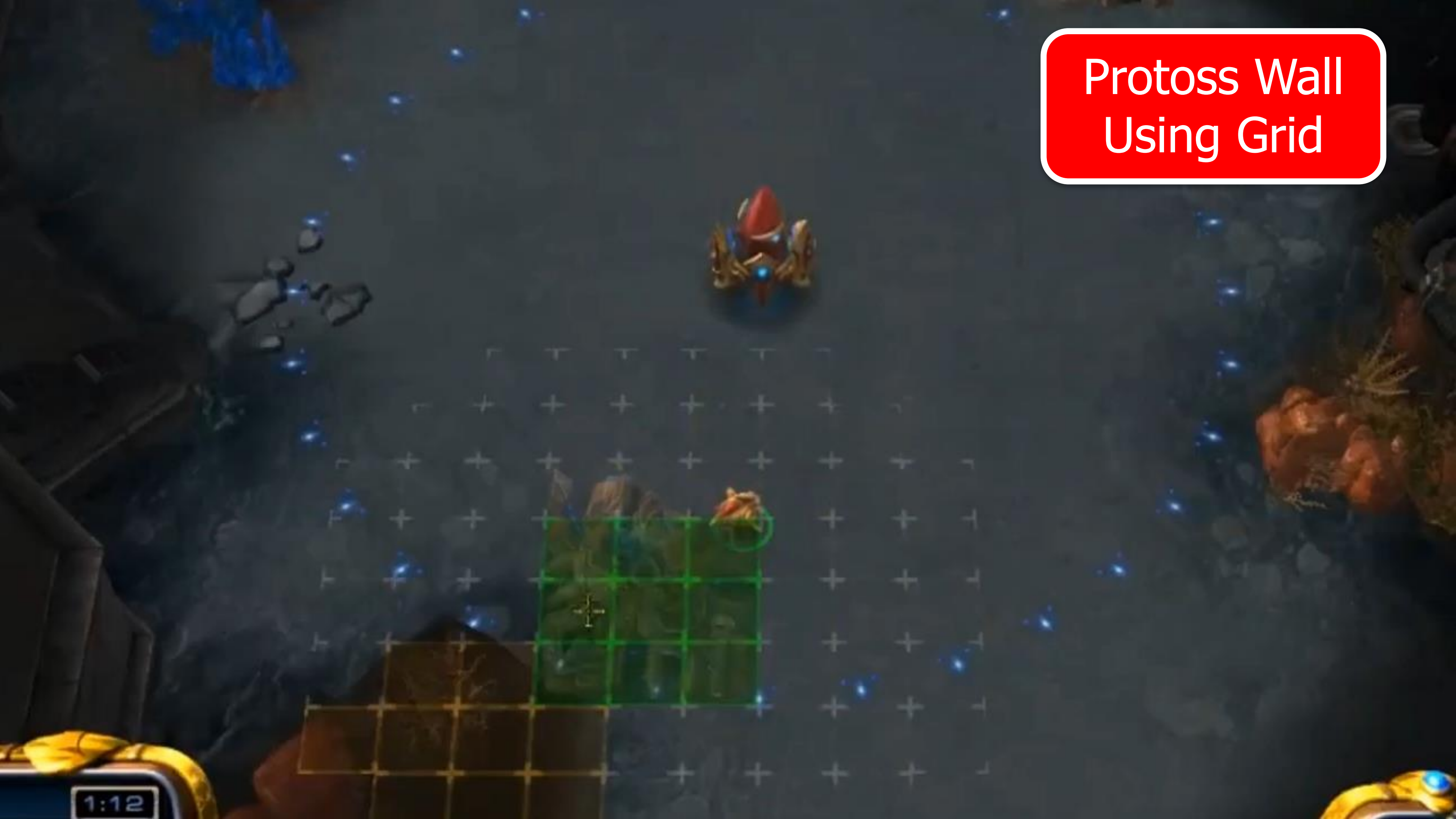
StarCraft Buildable Grid

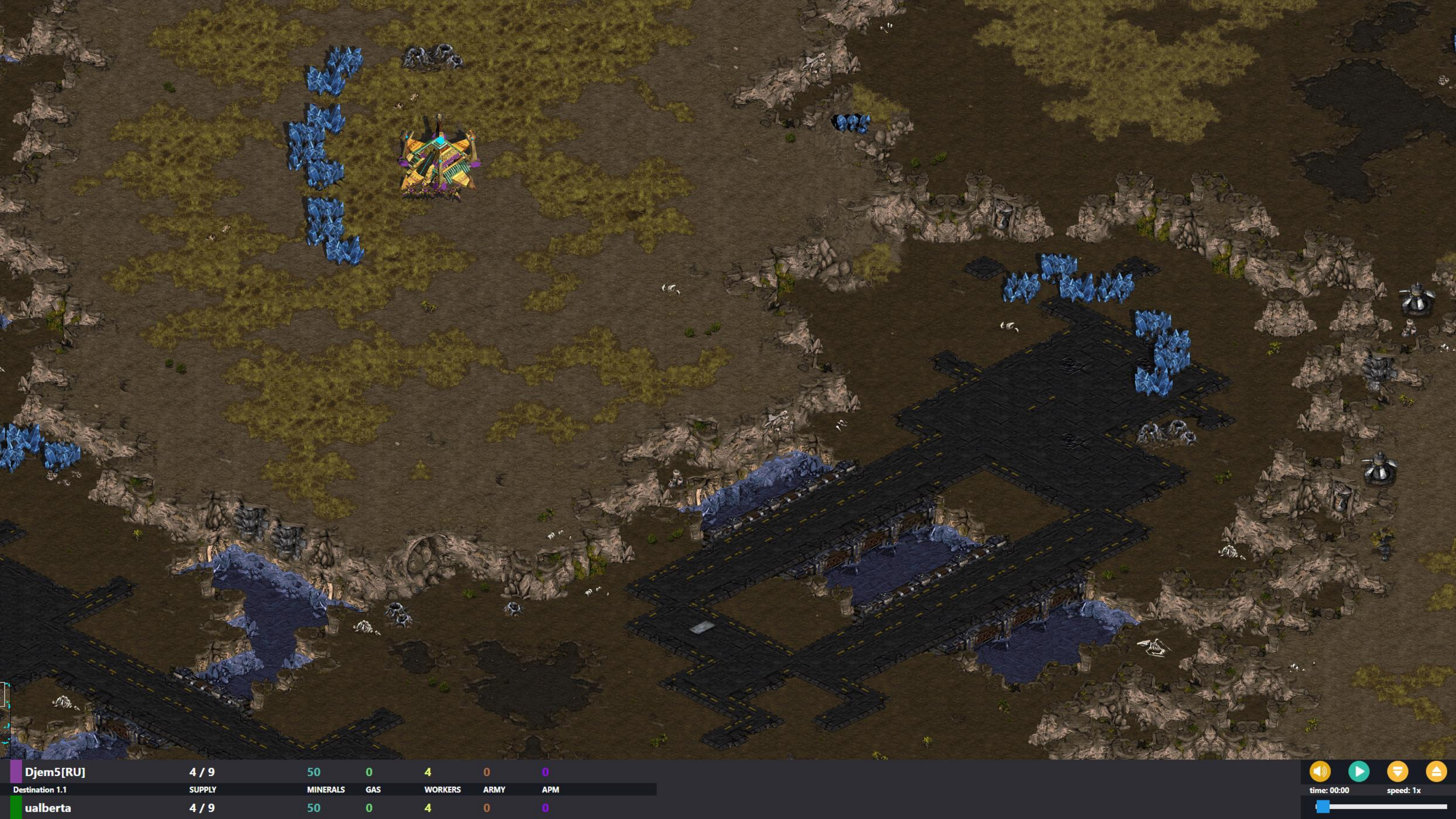


StarCraft 2 Buildable Grid



Protoss Wall Using Grid

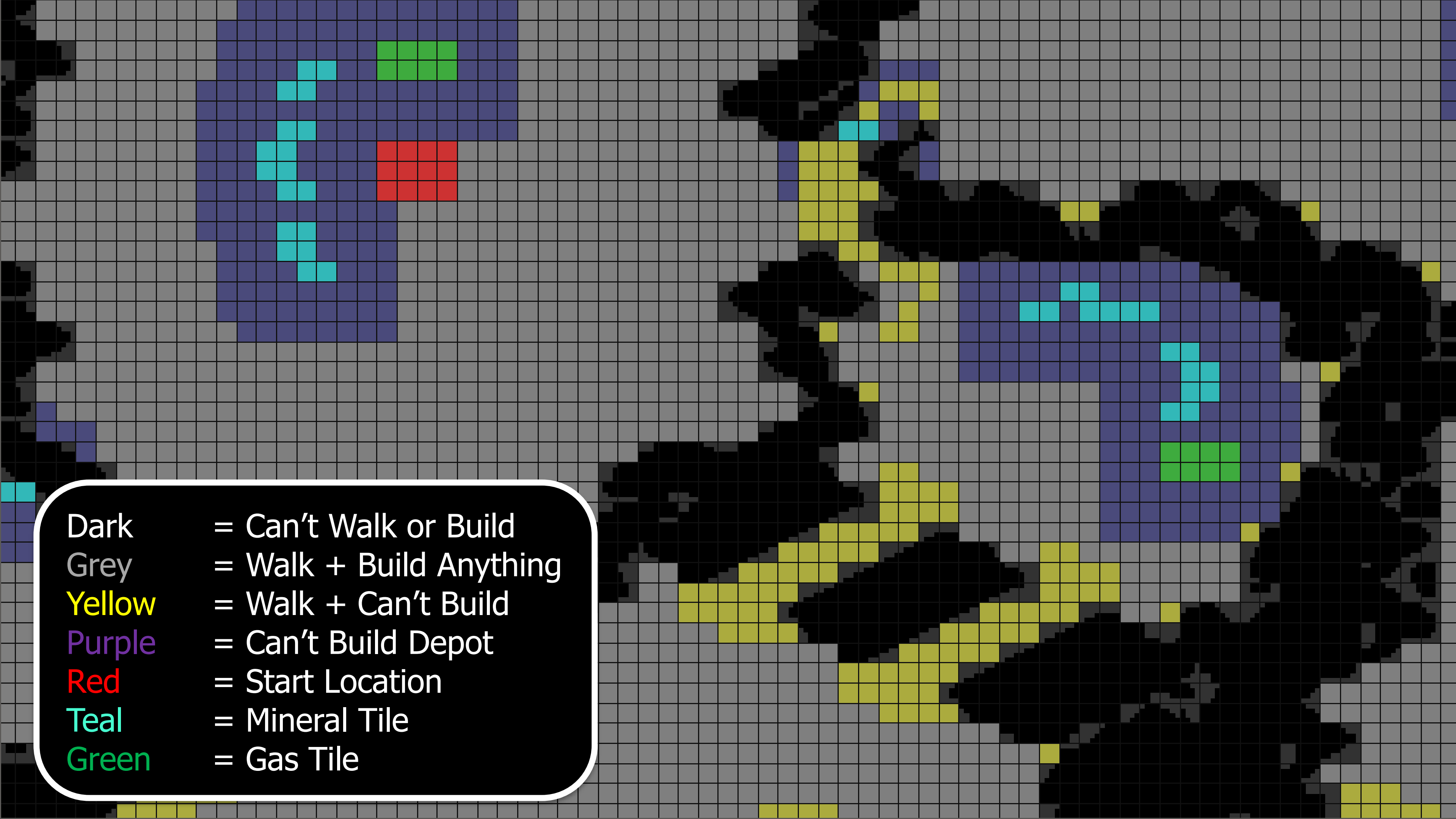




Destination 1.1	SUPPLY	MINERALS	GAS	WORKERS	ARMY	APM
Djem5[RU]	4 / 9	50	0	4	0	0
ualberta	4 / 9	50	0	4	0	0

time: 00:00

speed: 1x



Dark = Can’t Walk or Build

Grey = Walk + Build Anything

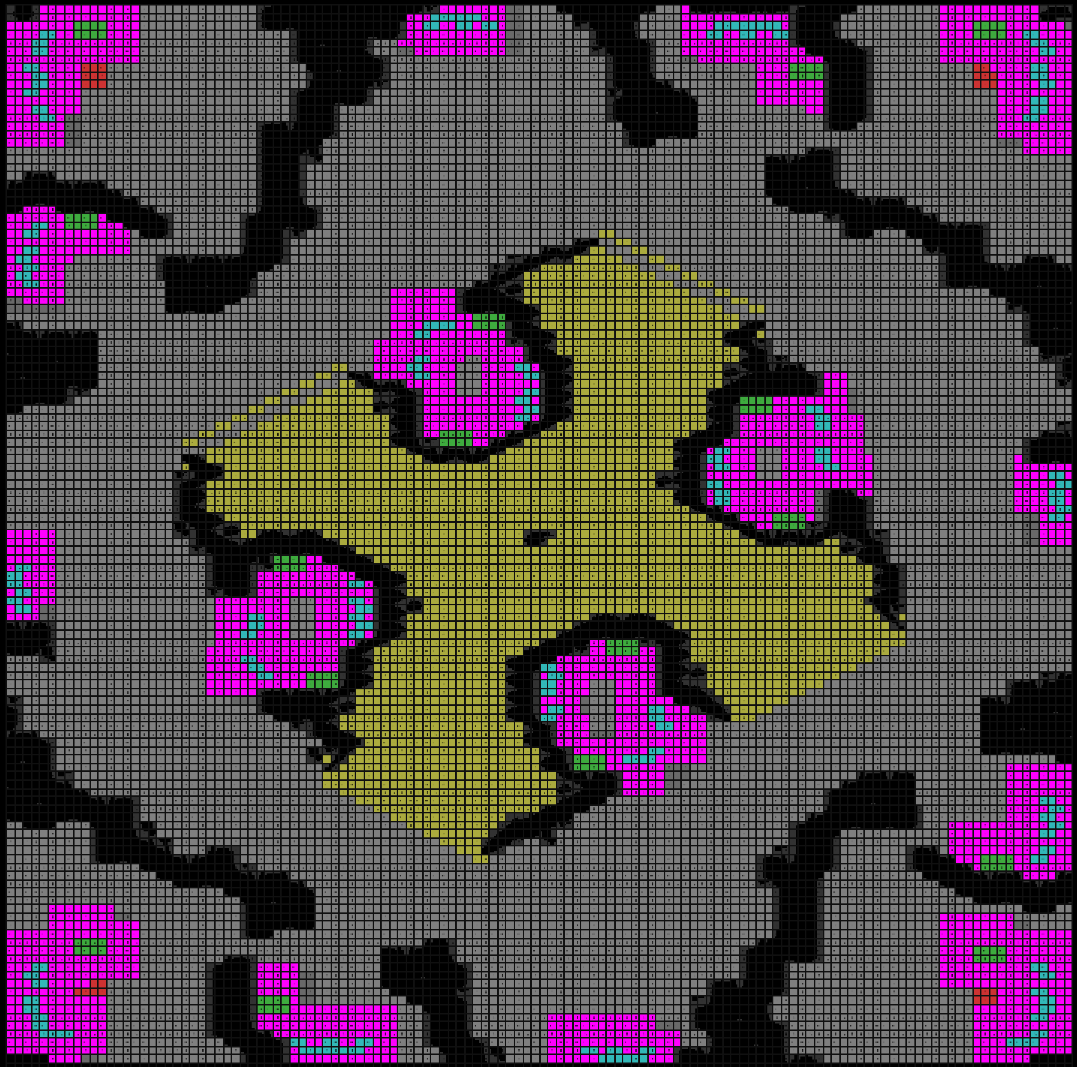
Yellow = Walk + Can’t Build

Purple = Can’t Build Depot

Red = Start Location

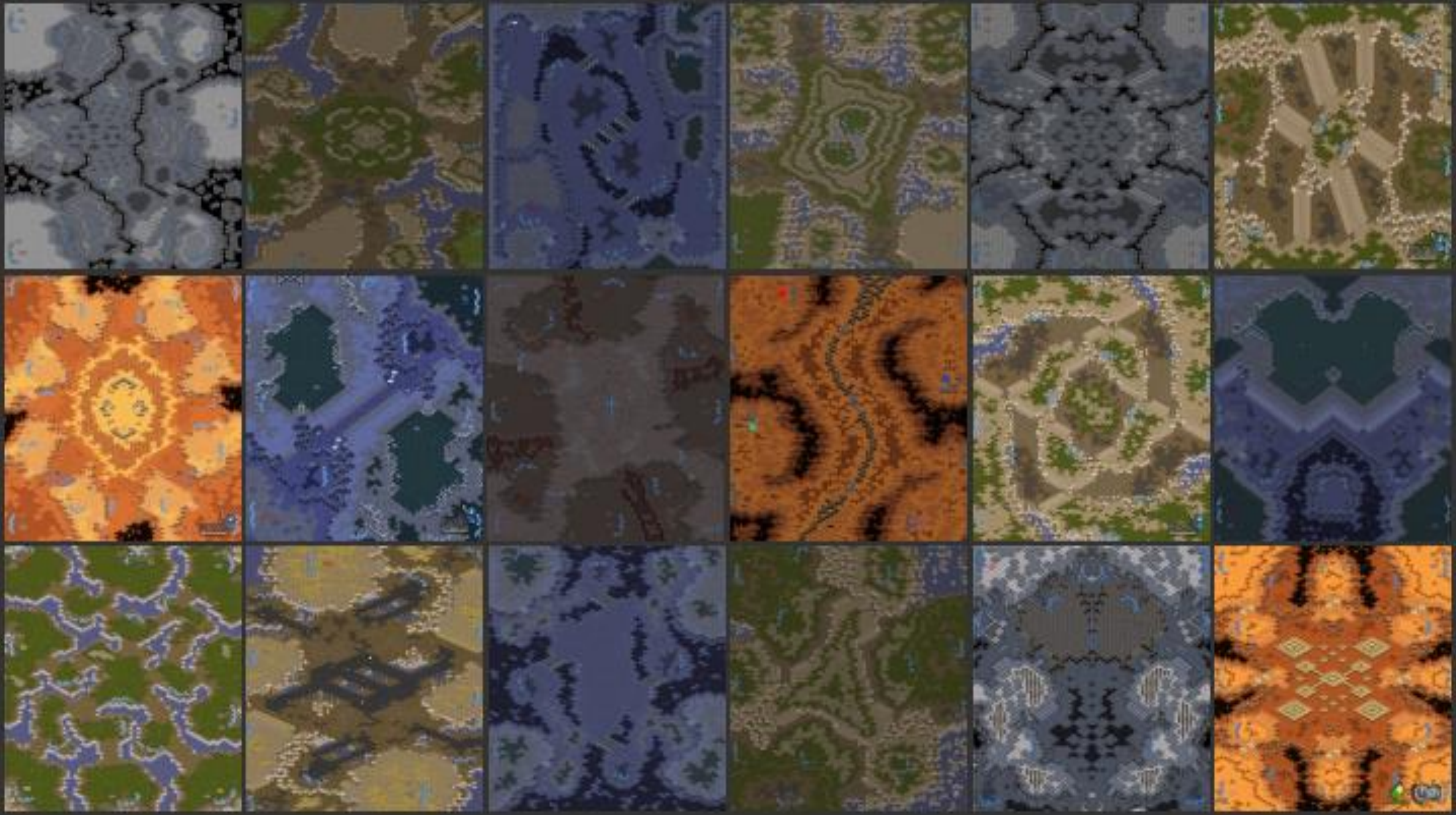
Teal = Mineral Tile

Green = Gas Tile



```
maps\ICCup_Wuthering_H.scx.txt
Size:    (128, 128) Build Tiles
         (512, 512) Walk Tiles
Memory: 278kb
Players: 4
```

Base Location Parsing

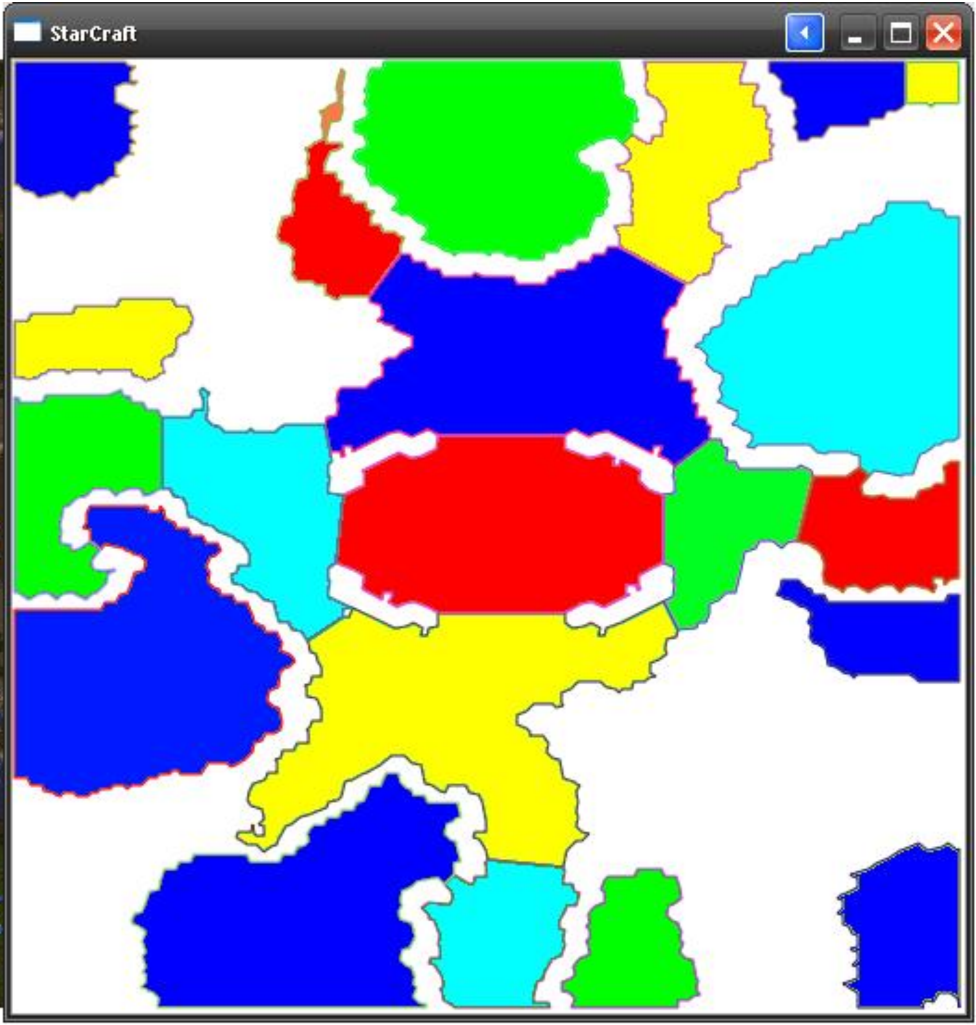


BWAPI Map Libraries

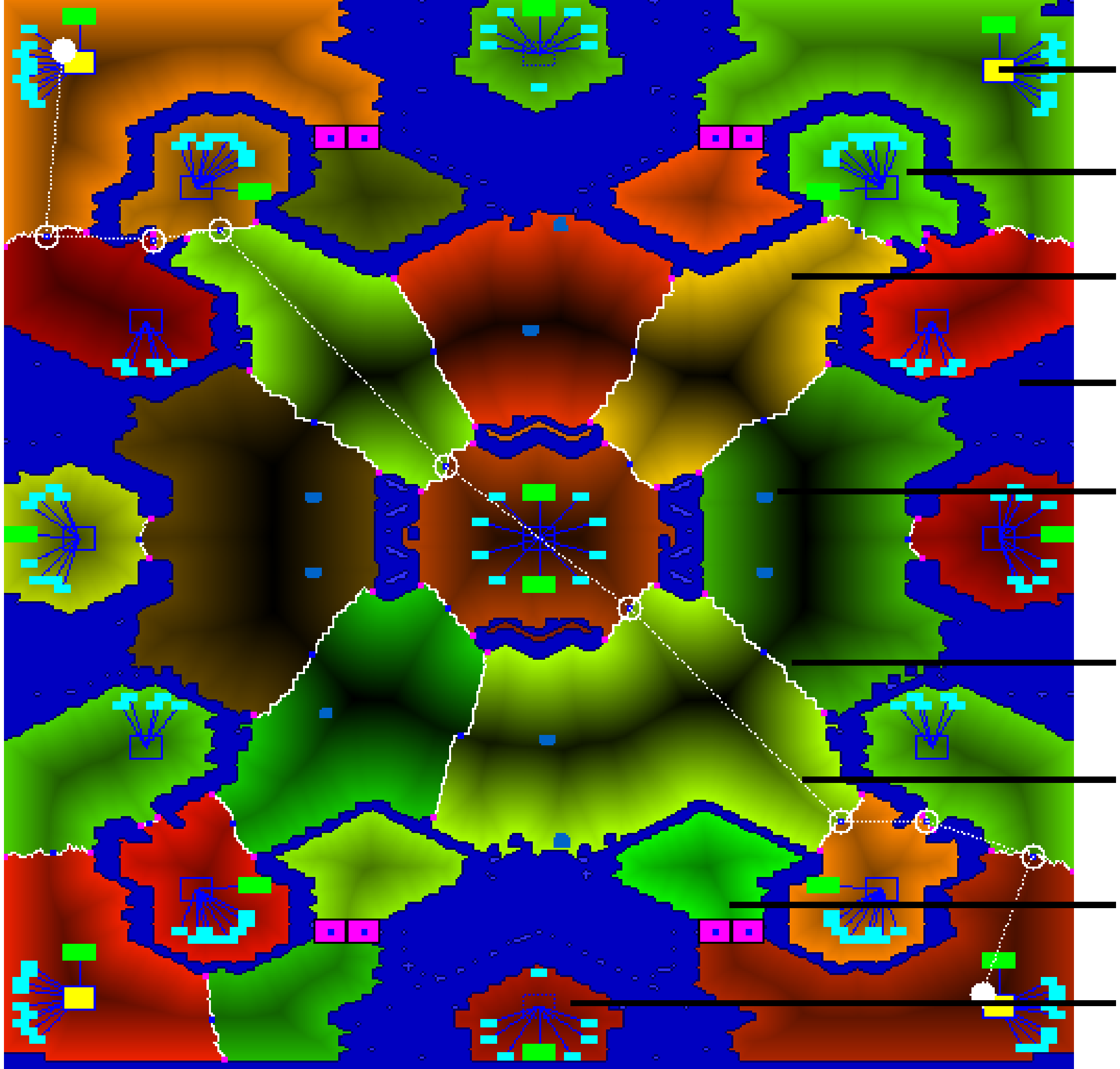
- Brood War Terrain Analysis
  - https://code.google.com/archive/p/bwta/
  - https://bitbucket.org/auriarte/bwta2/src/master/
- Brood War Easy Map
  - http://bwem.sourceforge.net/
  - https://github.com/N00byEdge/BWEM-community

BWEM-Community
(Recommended – Still Maintained)

BWTA



BWEM



Starting Base

Base with its assigned Ressources

Area with altitude rendered (min. dist. to Sea)

Sea = unwalkable zone

Lake = unwalkable zone inside an Area

ChokePoint

(shortest) Path between two starting Locations

two blocking Static Buildings

The dotted rectangle means the Base cannot be built before some close Mineral is gathered

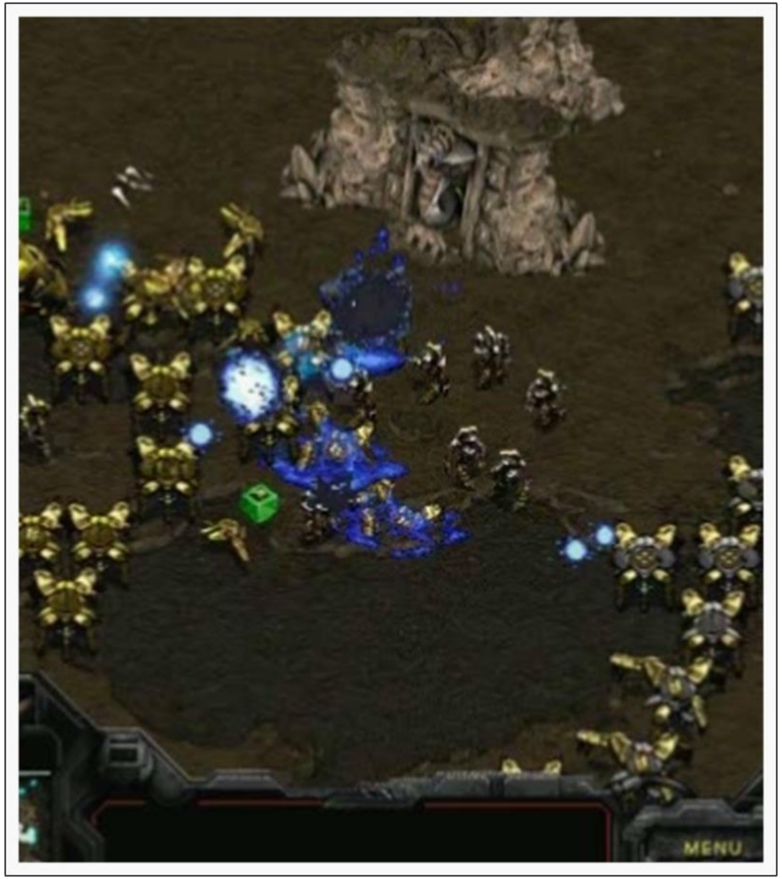
Scouting

- In order to attack your enemy, you need to know where their base is located
- Some maps have more than 2 starting locations, so you need to scout!
- Scouting is usually done with your worker unit after you have made a Supply Depot, Pylon, or Spawning Pool for Zerg

```cpp
void scoutWithUnit(BWAPI::Unit scout)
{
    if (!scout) { return; } // be sure we have a scout
    for (auto tile : BWAPI::Broodwar->getStartLocations())
    {
        if (!BWAPI::Broodwar->isExplored(tile))
        {
            BWAPI::Position pos(tile); // convert tile to pos
            auto command = scout->getLastCommand();
            // repeated command each frame can cause issues
            if (command.getTargetPosition() == pos) { return; }
            scout->move(pos);
            return;
        }
    }
    // if we have explored all start locations, return scout home
    scout->move(BWAPI::Position(BWAPI::Broodwar->self()->getStartLocation()));
}
```

Starcraft Combat

- Difficult Problem
- Goal: Kill enemy units
- Advanced tactics such as flanking / surround are hard to compute
- Attacking closest unit of enemy is good



Starcraft Bot Logic Flow

- https://github.com/davechurchill/ualbertabot/wiki/Design-and-Architecture

BWAPI Annoyances

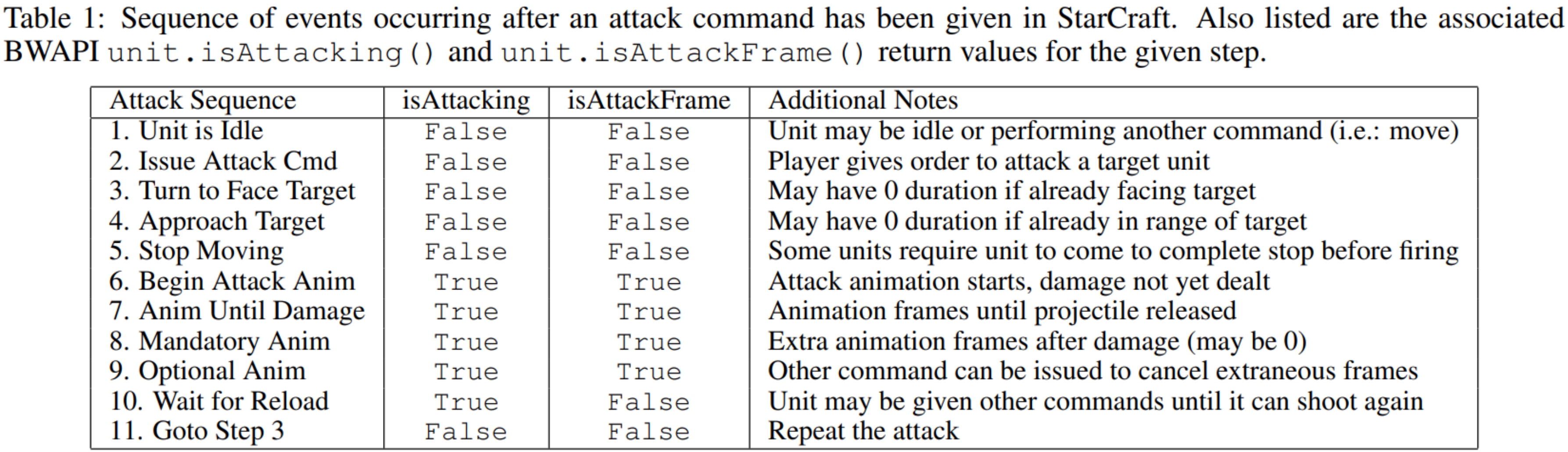


Table 1: Sequence of events occurring after an attack command has been given in StarCraft. Also listed are the associated BWAPI `unit.isAttacking()` and `unit.isAttackFrame()` return values for the given step.

Attack Sequence	isAttacking	isAttackFrame	Additional Notes
1. Unit is Idle	`False`	`False`	Unit may be idle or performing another command (i.e.: move)
2. Issue Attack Cmd	`False`	`False`	Player gives order to attack a target unit
3. Turn to Face Target	`False`	`False`	May have 0 duration if already facing target
4. Approach Target	`False`	`False`	May have 0 duration if already in range of target
5. Stop Moving	`False`	`False`	Some units require unit to come to complete stop before firing
6. Begin Attack Anim	`True`	`True`	Attack animation starts, damage not yet dealt
7. Anim Until Damage	`True`	`True`	Animation frames until projectile released
8. Mandatory Anim	`True`	`True`	Extra animation frames after damage (may be 0)
9. Optional Anim	`True`	`True`	Other command can be issued to cancel extraneous frames
10. Wait for Reload	`True`	`False`	Unit may be given other commands until it can shoot again
11. Goto Step 3	`False`	`False`	Repeat the attack

StarCraft Agents

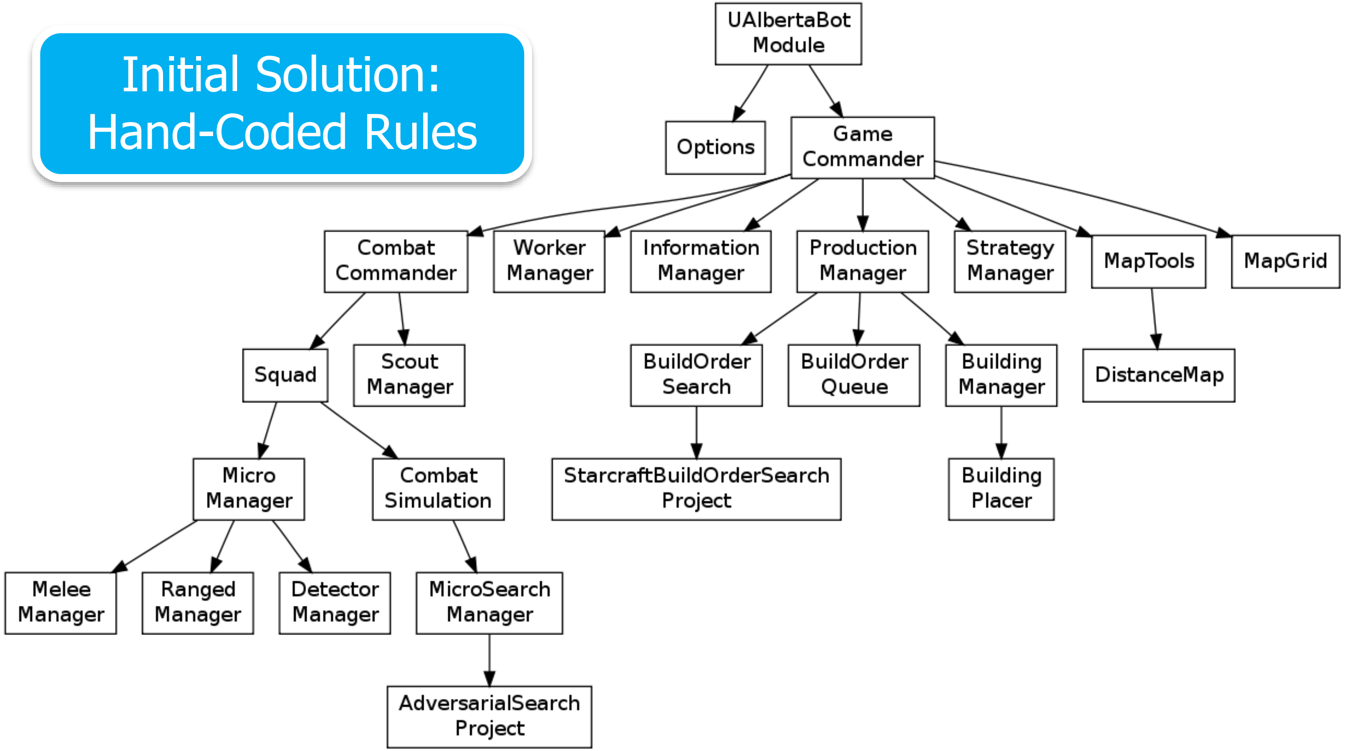
UAlbertaBot

- Competing since 2010

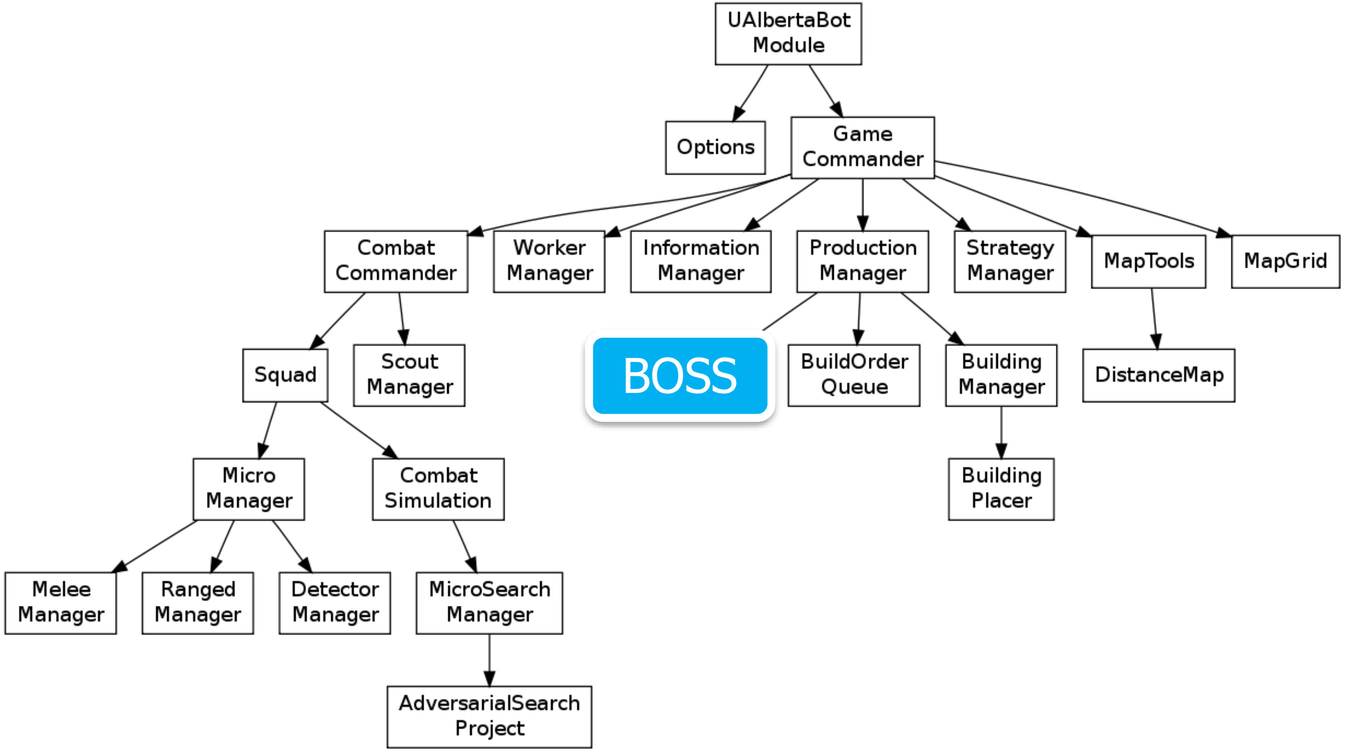
- Plays any of the 3 StarCraft races
- 10+ “Strategies”
- Best at “Rushing” strategies

UAlbertaBot

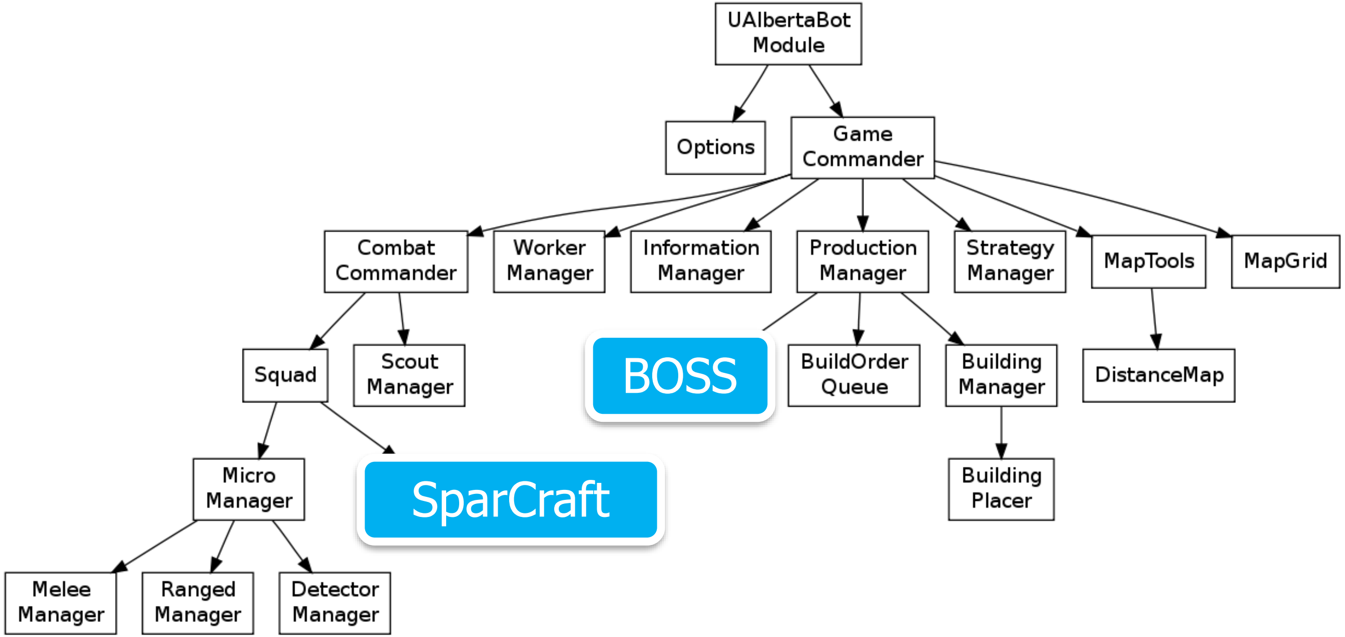
Initial Solution:
Hand-Coded Rules



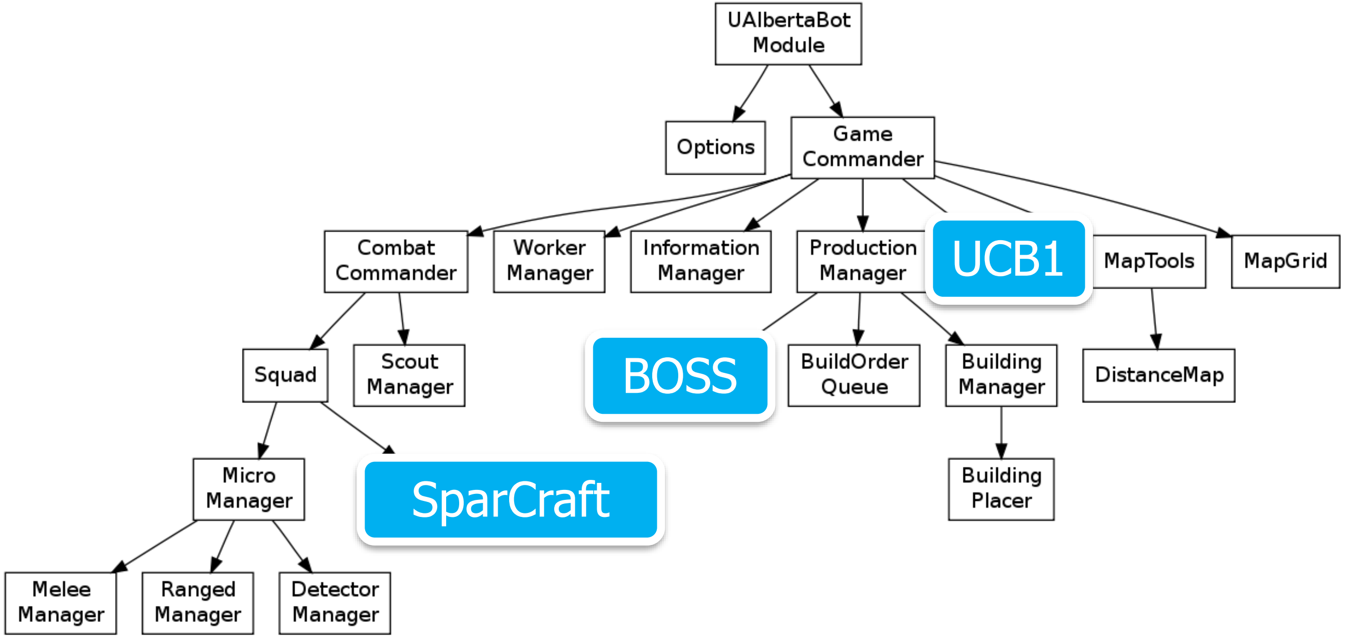
UAlbertaBot

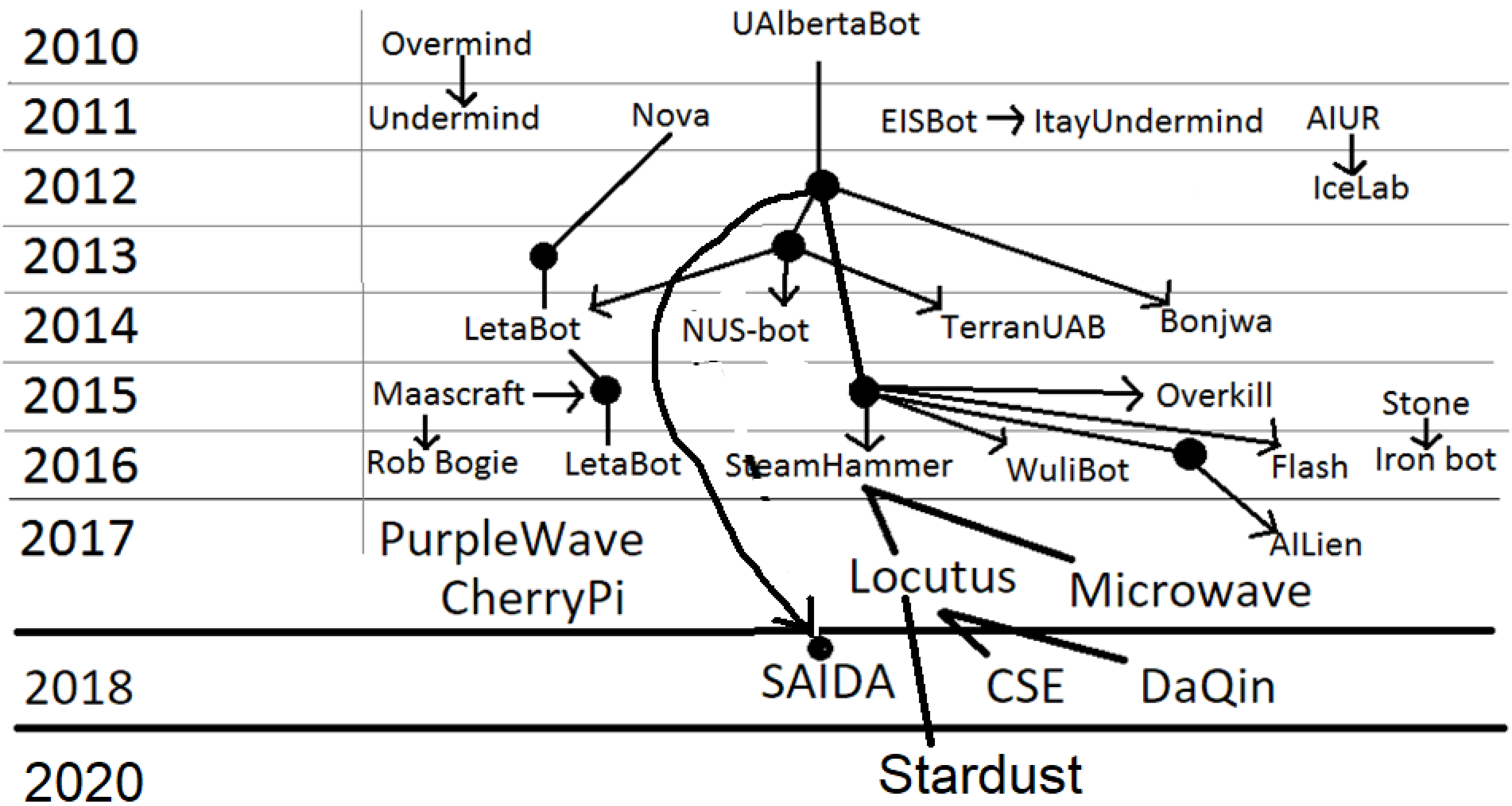


UAlbertaBot

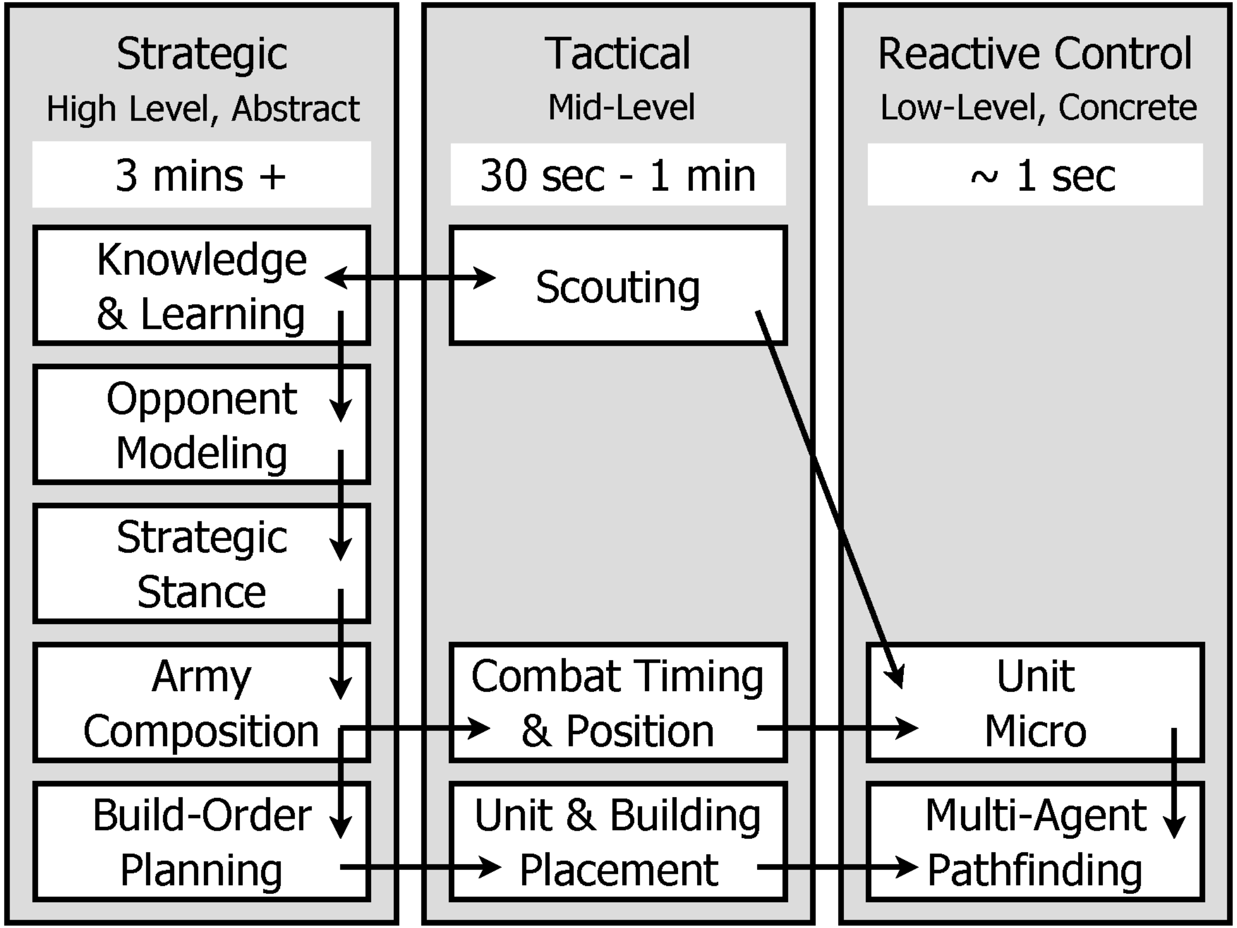


UAlbertaBot




2010
Overmind
UAlbertaBot
2011
Undermind
Nova
EISBot
ItayUndermind
AIUR
2012
IceLab
2013
2014
LetaBot
NUS-bot
TerranUAB
Bonjwa
2015
Maascraft
Overkill
Stone
2016
Rob Bogie
LetaBot
SteamHammer
WuliBot
Flash
Iron bot
2017
PurpleWave
CherryPi
AILien
Locutus
Microwave
2018
SAIDA
CSE
DaQin
2020
Stardust

StarCraft (Huge)



Strategic
High Level, Abstract
3 mins +

Knowledge & Learning

Opponent Modeling

Strategic Stance

Army Composition

Build-Order Planning

Tactical
Mid-Level
30 sec - 1 min

Scouting

Combat Timing & Position

Unit & Building Placement

Reactive Control
Low-Level, Concrete
~ 1 sec

Unit Micro

Multi-Agent Pathfinding

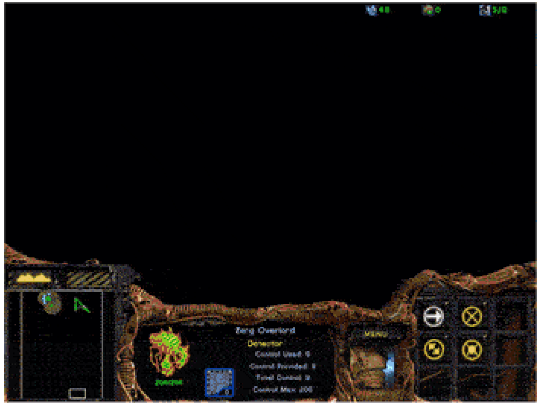
StarCraft as an AI Environment

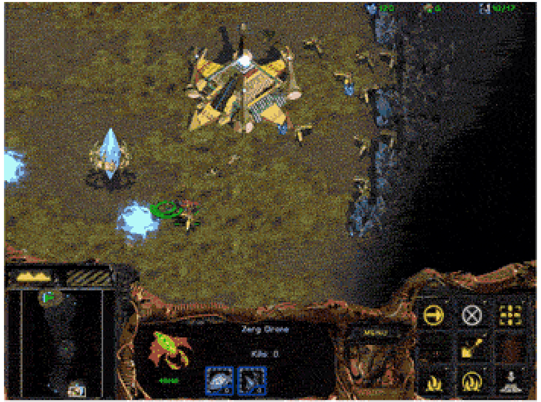
- Huge action / state space
- Real-time decision making
- Properties similar to real-life problems
- New solutions required, not just more CPU
- Human experts can evaluate agents
- Public interest / excitement
- Educational tool / student motivation

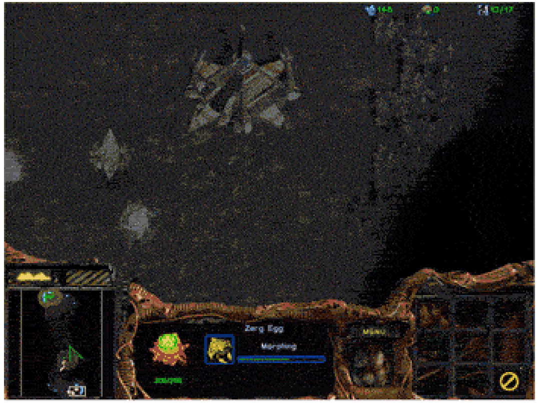
Properties of RTS

- Real-Time
- Simultaneous Move
- Non-Deterministic
- Imperfect Information
- Multi-Unit Control
- Unknown Game Engine
- Action / State Space

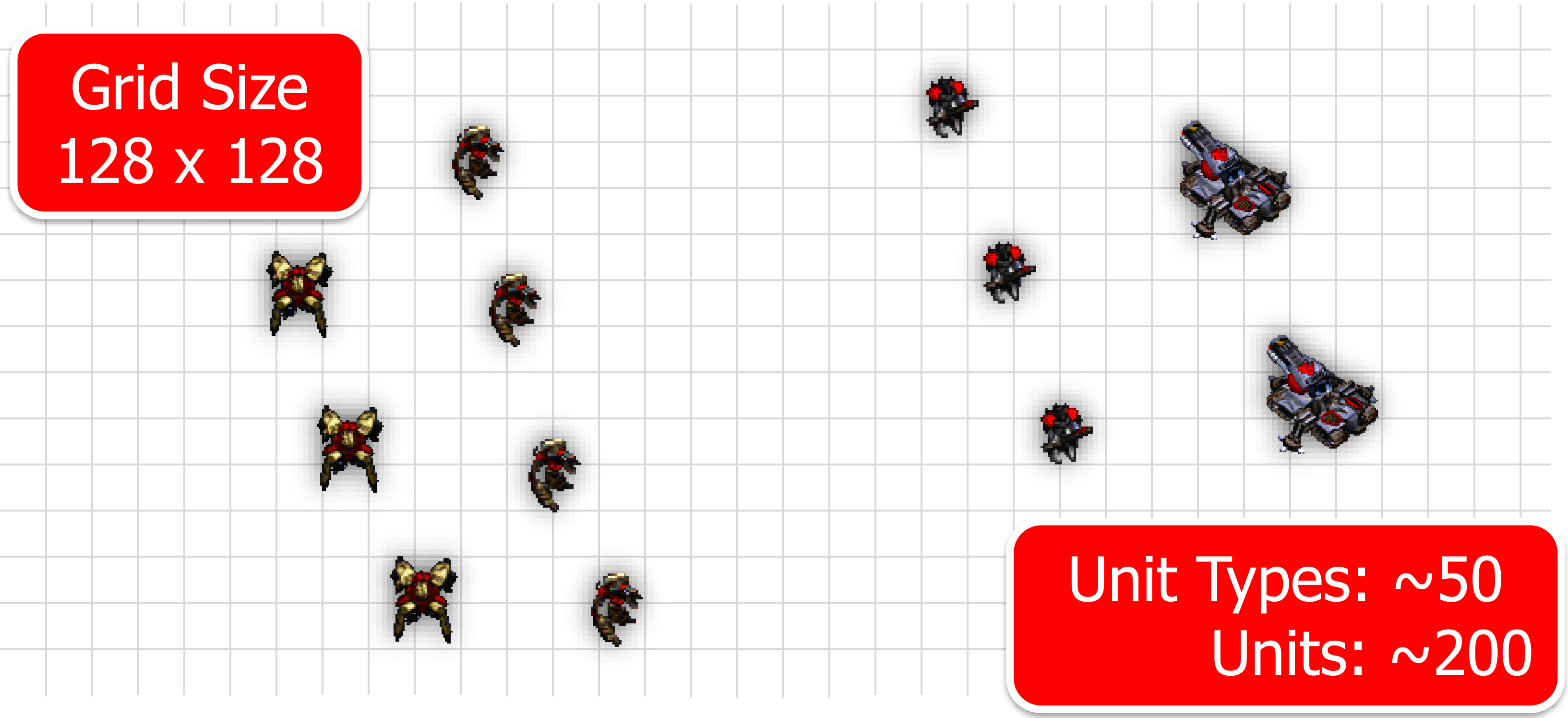
Imperfect Information







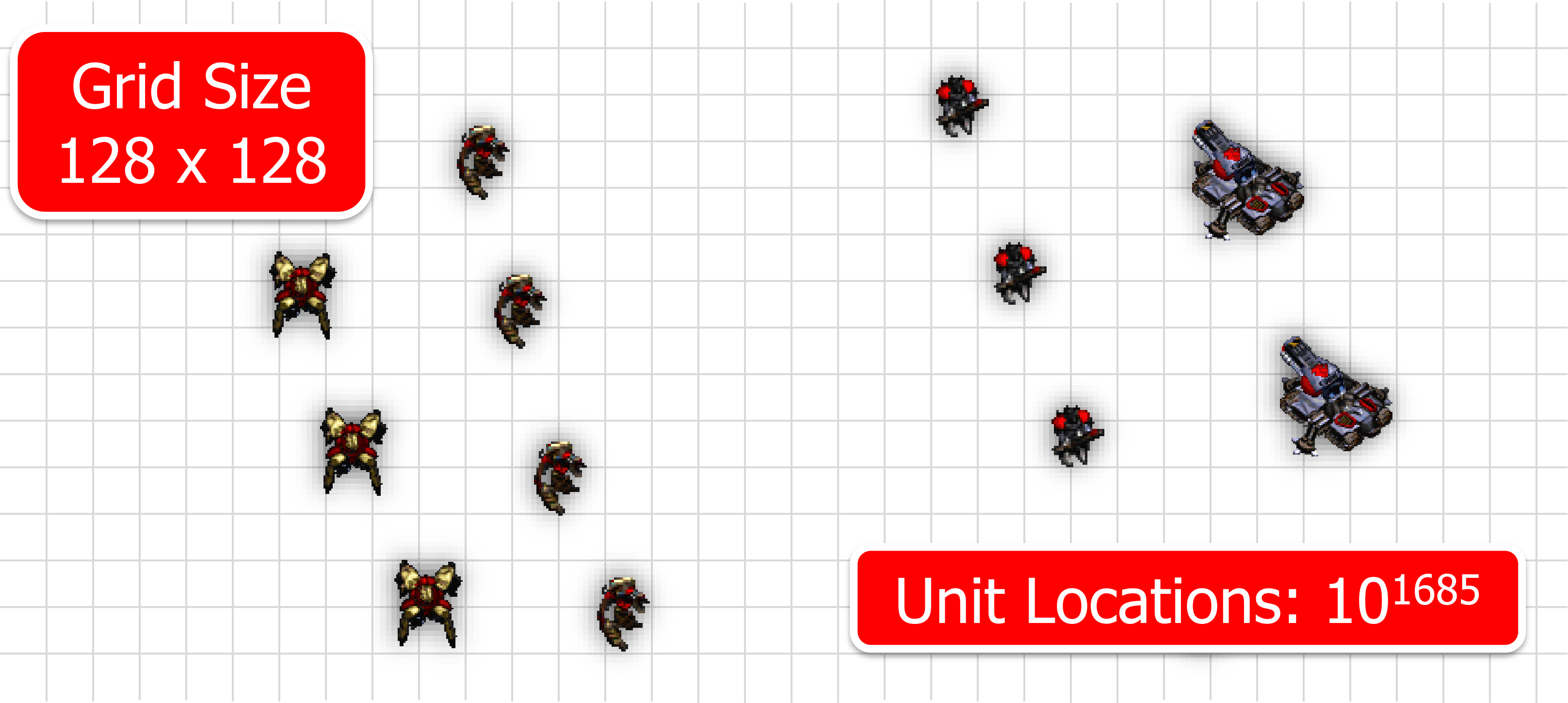
State Space



Grid Size
128 x 128

Unit Types: ~50
Units: ~200

State Space

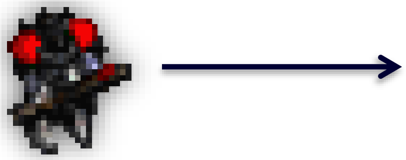


Grid Size
128 x 128

Unit Locations: 10^{1685}

Multi-Unit Control

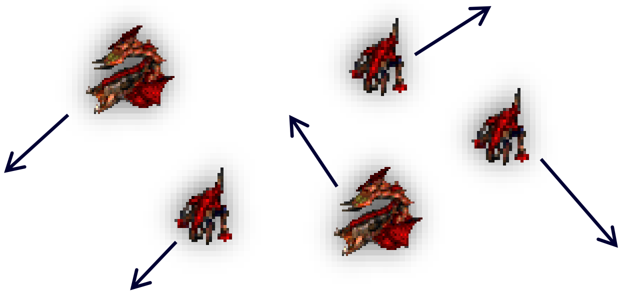
Unit Action



# Units = U

# Actions = A

Player Move



Player Moves ~ A^U

Properties of RTS

- Real-Time
- Simultaneous Move
- Non-Deterministic
- Imperfect Information
- Multi-Unit Control
- Unknown Game Engine
- Action / State Space

Properties of Robotics

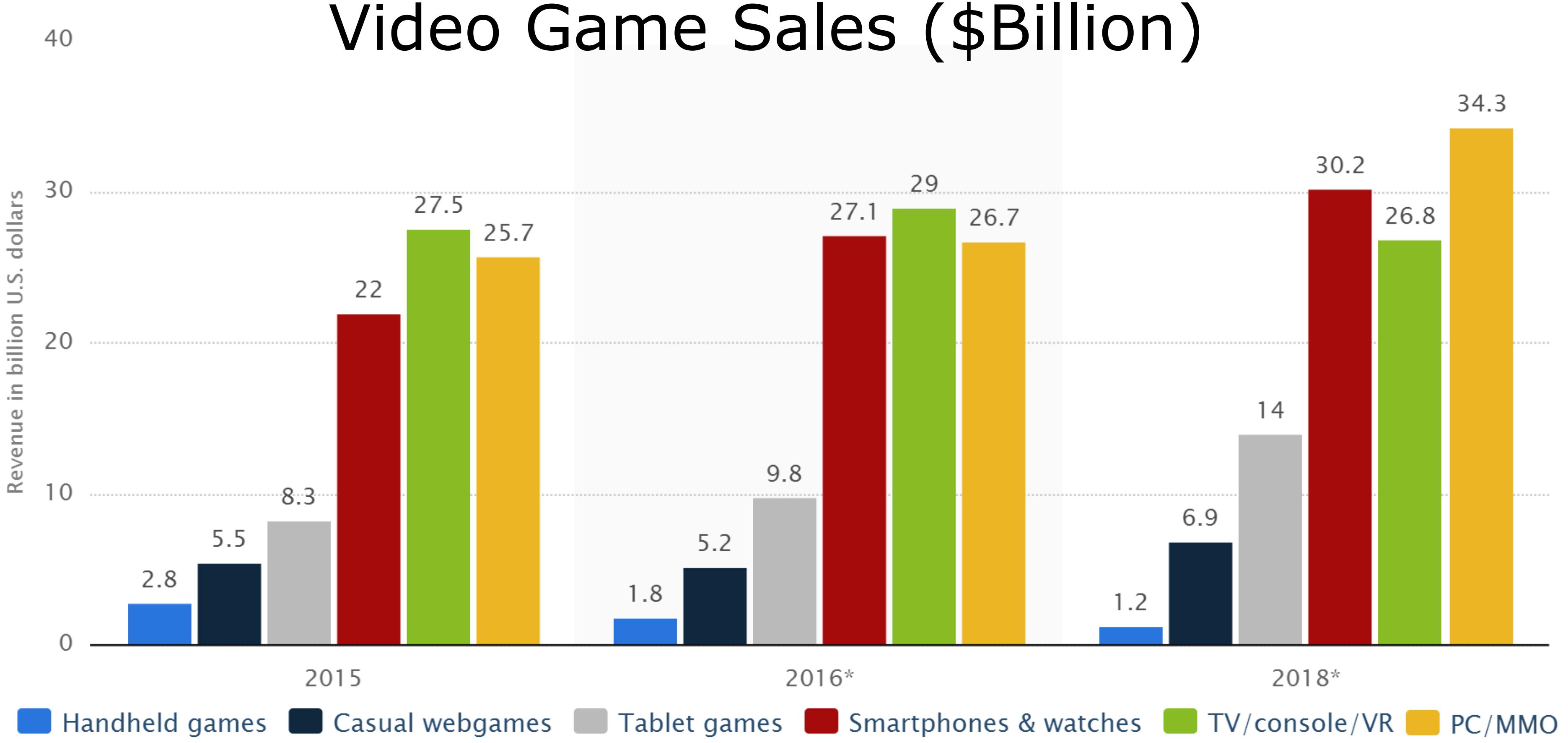
- Real-Time
- Simultaneous Move
- Non-Deterministic
- Imperfect Information
- Multi-Unit Control
- Unknown Game Engine
- Action / State Space

Properties of the Real World

- Real-Time
- Simultaneous Move
- Non-Deterministic
- Imperfect Information
- Multi-Unit Control
- Unknown Game Engine
- Action / State Space

http://www.statista.com/statistics/278181/video-games-revenue-worldwide-from-2012-to-2015-by-source/

Video Game Sales ($Billion)



Benefits of RTS AI

- Better In-Game AI
  - More intelligent NPCs
  - Better single player
- Create Offline Tools
  - Game balancing
  - Reduce human testing
- Apply to any game

Human Professionals

300-500 Actions Per Minute (APM)

Human vs. Machine