

Introduction:

This is a very brief guide to writing a pop file. It does **NOT** cover absolutely everything in MvM mission making by any stretch of the imagination, but it should be enough to get you started. If you have any questions, ask in our group chat or in our mission making Q&A thread.

This guide assumes you are writing your pop file by hand on a text editor like **Notepad++**.

Planning:

Before you even open a blank pop file, you need to plan your mission out. Ask yourself these questions:

- What kinds of robots do I want to feature (spawn) in each wave?
- At what order do I want the robots to spawn in?
- How much money do I want to pay out in each wave?
- *(If the map supports it)* Do I want to feature tanks in some of these waves?
- Do I want to have infinite support robots in the wave? If so, which robot(s) and when?
- Do I want to make my own robots or should I use Valve robots?
- What type of objective support bots do I want to feature in this wave? *(Note: Engineer bots require special entity work on the map, so not all maps will support engineers.)*

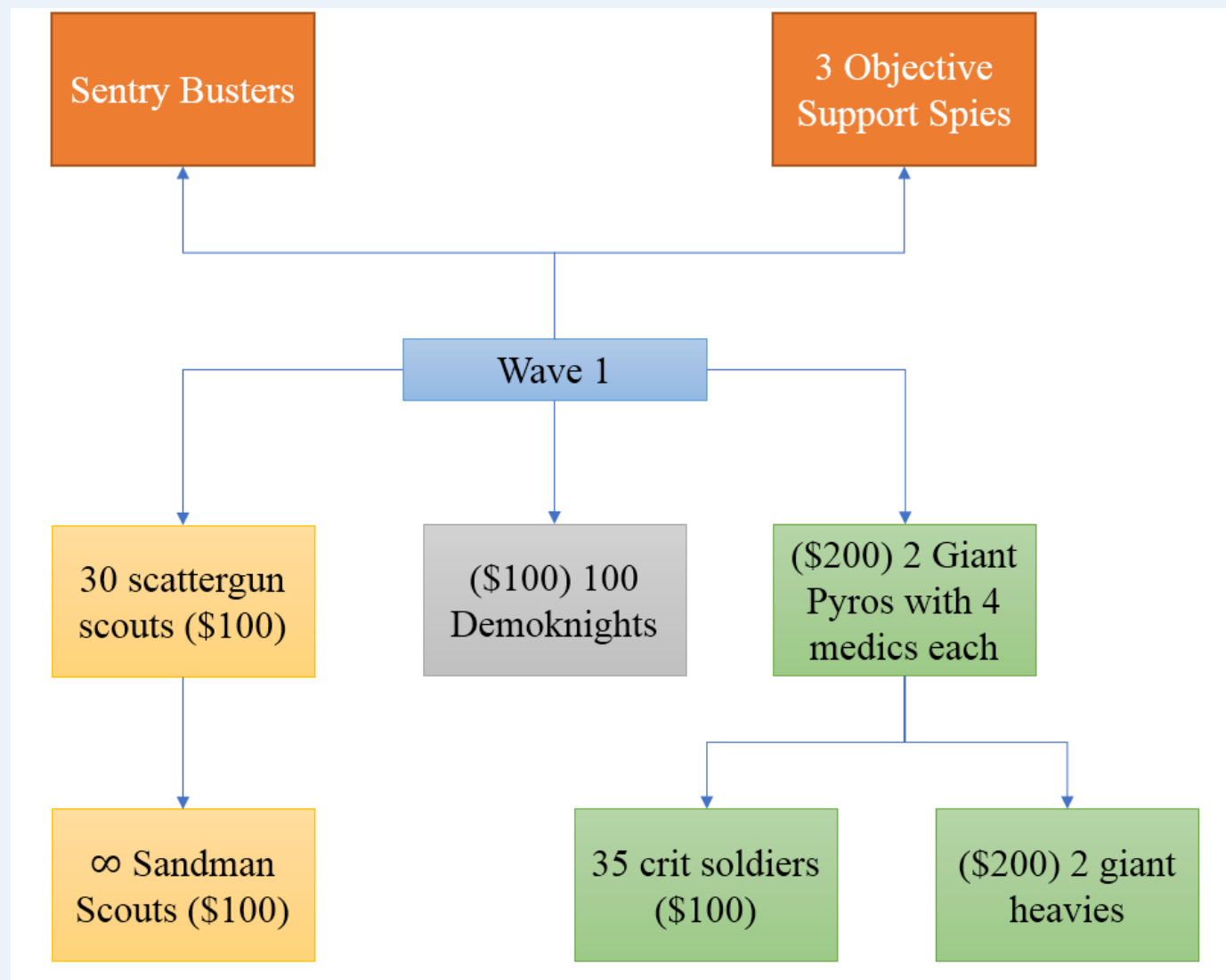
The planning stage varies from person to person, but this is how I would outline a 2 wave mission:

- 1) Wave 1 (\$800 total)
 - a) (\$100) 30 scattergun scouts
 - b) (\$100) 100 demoknights (sporadically across the whole wave)
 - c) (\$200) 2 giant pyros with 4 uber medics each
 - d) (\$100) Infinite support sandman scouts (after scattergun scouts die)
 - e) (\$100) 35 crit soldiers (after the giant pyros finish spawning)
 - f) (\$200) 2 giant heavies (after giant pyros die)
 - g) (-) 4 objective support spies
 - h) (-) Sentry busters
- 2) Wave 2 (\$1000 total)
 - a) (\$200) 2 tanks (one on each tank path)
 - b) (\$200) 5 super scouts
 - c) (\$100) 16 crit iron bomber demos
 - d) (\$100) 20 deflector heavies with an uber medic on each
 - e) (\$200) 5 giant soldiers (after the tanks AND giant scouts all die)
 - f) (\$100) Infinite support crit combat medics (after the deflector heavies finish spawning)
 - g) (\$100) 40 pyros on expert AI (after the crit iron bomber demos all die)
 - h) (-) 2 objective support Sydney sleeper snipers
 - i) (-) 3 objective support spies
 - j) (-) Sentry busters

The more detailed your outline is, the easier it will be to write your pop file. Don't spend too much time spelling out every detail however as that will slow you down and make your outline messy, but putting some thought here will make the coding process less obnoxious. The outline is between 70-80% of the work needed to make an advanced mode mission. The remaining 20% is the actual syntax of pop files.

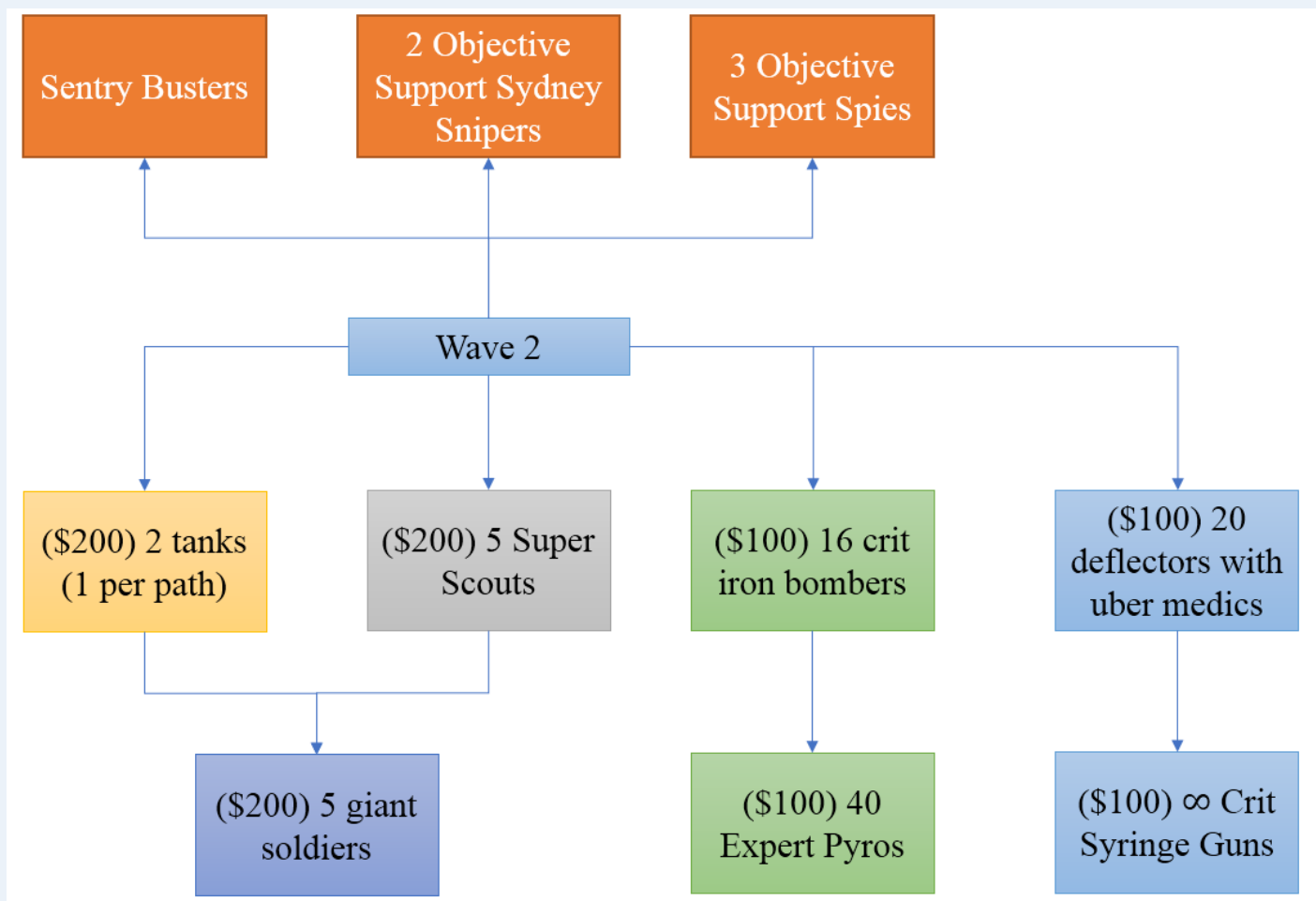
If you're more of a visual person, your outline may look like this instead. This is more-or-less how the population manager works – the spawning logic works somewhat like a tree. While the pop file itself looks quite linear with a bunch of subwaves (“wavespawns”) one after the other, internally the spawning order will resemble something like this, so thinking about it this way may help you plan your waves.

The outline for wave 1 visually would look something like this:



- 1) Wave 1 (\$800 total)
 - a. (\$100) 30 scattergun scouts
 - b. (\$100) 100 demoknights (sporadically across the whole wave)
 - c. (\$200) 2 giant pyros with 4 uber medics each
 - d. (\$100) Infinite support sandman scouts (after scattergun scouts die)
 - e. (\$100) 35 crit soldiers (after the giant pyros finish spawning)
 - f. (\$200) 2 giant heavies (after giant pyros die)
 - g. (-) 3 objective support spies
 - h. (-) Sentry busters

Wave 2 would look something like this:



2) Wave 2 (\$1000 total)

- a. (\$200) 2 tanks (one on each tank path)
- b. (\$200) 5 super scouts
- c. (\$100) 16 crit iron bomber demos
- d. (\$100) 20 deflector heavies with an uber medic on each
- e. (\$200) 5 giant soldiers (after the tanks AND giant scouts all die)
- f. (\$100) Infinite support crit combat medics (after the deflector heavies finish spawning)
- g. (\$100) 40 pyros on expert AI (after the crit iron bomber demos all die)
- h. (-) 2 objective support Sydney sleeper snipers
- i. (-) 3 objective support spies
- j. (-) Sentry busters

Each person has their own way of planning out their waves. Find the approach that works best for you.

Construction:

Now that your outline is done, it's time to start writing your pop file. Without thinking about it, just type all of this in. (You don't need to include line 1 – lines that start with a `//` are comments which are ignored by the server when it loads your pop file.)

```
1 // Imports bot templates from other pop files (Valve robots in this case).
2 #base robot_giant.pop
3 #base robot_standard.pop
4
5 WaveSchedule
6 {
7
8 }
9
```

Now inside the `WaveSchedule` section, add the following: (You do not need to add the comments.)

```
5 WaveSchedule
6 {
7     // Init
8     StartingCurrency 1500
9     RespawnWaveTime 6
10    CanBotsAttackWhileInSpawnRoom no
11
12    // Bot templates
13    Templates
14    {
15        .....
16    }
17 }
18
```

The **StartingCurrency** specifies how much money players start off with before they play wave 1. In the above case, it is \$1500 so they will have \$1500 to spend on upgrades before they start the mission.

The **RespawnWaveTime** specifies the amount of time players must wait every time they die to respawn back into the map. This number increases by 2 for every wave that is completed. In the example, it's set to 6, so wave 1 has a 6 sec respawn time, wave 2 has an 8 sec respawn time, etc.

The **CanBotsAttackWhileInSpawnRoom** is rather self-explanatory – can bots attack while they are in their spawnroom area? Unless you're making a gimmick mission or really know what you're doing, you almost-always want to leave this as “no”.

The **Templates** section is where you can put custom robot templates (a bot template is like the DNA of mvm robots in some sense – it tells the server how to construct the robot and its abilities). We will discuss this more in detail. If you are only going to use Valve robots, you do not need to include that section.

Now we will include the objective mission robots, like sentry busters, snipers, and spies. These are “mission” robots, and they are declared under a mission section.

Here is an example for a sentry buster mission:

```
18 // Missions
19 Mission
20 {
21     Objective DestroySentries
22     InitialCooldown 20
23     Where spawnbot
24     BeginAtWave 1
25     RunForThisManyWaves 9
26     CooldownTime 20
27     DesiredCount 1
28     TFBot
29     {
30         Template T_TFBot_SentryBuster
31     }
32 }
```

The **Objective** tells the bot AI what it should do. In this case, it tells the bot to find sentry guns to destroy.

The **InitialCooldown** is the cooldown period before this bot can start spawn in. It's set to 20 seconds, so the sentry buster will not spawn for 20 seconds after the wave starts.

The **Where** tells the bot where it should spawn (specifically, which *info_player_teamspawn*, or more informally known as a spawn point). The value here should be the name of a valid *info_player_teamspawn* entity on the map. You can get the list of spawn point names from either looking at the map's pop files or decompiling the map and inspecting the *info_player_teamspawn* in hammer.

You must provide a valid spawnpoint or else the bots will not spawn.

The **BeginAtWave** tells the server on which wave the bot is allowed to spawn in. Here it's set to 1, so the bot can spawn starting in wave 1.

The **RunForThisManyWaves** tells the server for how many waves this bot is allowed to appear in as an objective support bot. Here it's set to 9, so the bot can spawn in waves 1-9 (inclusive).

The **CooldownTime** is the cooldown spawn interval time between bot spawns. It's like the speed cap or the throttle for bot spawns. A bot cannot spawn more frequently than after this many seconds. In this case, a sentry buster cannot spawn more often than every 20 seconds.

The **DesiredCount** is the number of bots to spawn every time after the cooldown timer elapses. Here it's set to 1, so only 1 bot will spawn after the cooldown expires. After that bot is killed, it will wait for the *CooldownTime* number of seconds before spawning the *DesiredCount* number of bots again.

The **TFBot** section has the robot template (the type of robot) that will be spawned when this mission decides to spawn robots into the map. Here it's referencing the Valve sentry buster template. Templates will be discussed more in detail later.

As another example for *BeginAtWave* and *RunForThisManyWaves*, if *BeginAtWave* is 3 and *RunForThisManyWaves* is 4, then the mission bot will run for waves 3-6 **inclusive**. The starting wave number is whatever *BeginAtWave* is at, and the ending wave number is:

$$\text{Starting Wave} = \text{BeginAtWave} = 3$$

$$\text{Ending Wave} = \text{BeginAtWave} + \text{RunForThisManyWaves} - 1 = 3 + 4 - 1 = 6$$

Operation Titanium Tank: A Guide to MvM Wave Writing

Most missions have sentry busters in them or else engineers would have a massive hayday with their sentry gun, so you will almost-always have the sentry buster mission declaration in every pop file you make. Now our outline said we want spies on waves 1 & 2 and a Sydney sleeper spy on wave 2, so let's toss those in as well:

- 1) Wave 1 (\$800 total)
 - a. (-) 3 objective support spies
 - b. (-) Sentry busters
- 2) Wave 2 (\$800 total)
 - a. (-) 2 objective support Sydney sleeper snipers
 - b. (-) 3 objective support spies
 - c. (-) Sentry busters

```
18 // Sentry buster mission
19 Mission
20 {
21     Objective DestroySentries
22     InitialCooldown 20
23     Where spawnbot
24     BeginAtWave 1
25     RunForThisManyWaves 9
26     CooldownTime 20
27     DesiredCount 1
28     TFBot
29     {
30         Template T_TFBot_SentryBuster
31     }
32 }
33
34 // Wave 1 & 2 spies
35 Mission
36 {
37     Objective Spy
38     InitialCooldown 90
39     Where spawnbot_mission_spy
40     BeginAtWave 1
41     RunForThisManyWaves 2
42     CooldownTime 60
43     DesiredCount 3
44     TFBot
45     {
46         Template T_TFBot_Spy
47     }
48 }
49
50 // Wave 2 sydney snipers
51 Mission
52 {
53     Objective Sniper
54     InitialCooldown 120
55     Where spawnbot_mission_sniper
56     BeginAtWave 1
57     RunForThisManyWaves 1
58     CooldownTime 60
59     DesiredCount 2
60     TFBot
61     {
62         Template T_TFBot_Sniper_Sydney_Sleeper
63     }
64 }
```

For the spies, we can declare the wave 1 & 2 spies under one *Mission* block since they have the exact same spawning and bot properties. However, if we wanted to change **any** one bit of the spy mission for any of the waves, you would need to declare a whole new Mission block, change the *BeginAtWave* and *RunForThisManyWaves*, and tweak whatever else it is that you wanted to change. For example, let's say on wave 2 I wanted 45 seconds cooldown instead of 60. I would have to do this instead:

```

34      // Wave 1 spies
35      Mission
36      {
37          Objective Spy
38          InitialCooldown 90
39          Where spawnbot_mission_spy
40          BeginAtWave 1           // Start at wave 1
41          RunForThisManyWaves 1   // Run this only for wave 1
42          CooldownTime 60
43          DesiredCount 3
44          TFBot
45          {
46              Template T_TFBot_Spy
47          }
48      }
49
50      // Wave 2 spies
51      Mission
52      {
53          Objective Spy
54          InitialCooldown 90
55          Where spawnbot_mission_spy
56          BeginAtWave 2           // Start at wave 2
57          RunForThisManyWaves 1   // Run this only for wave 2
58          CooldownTime 45
59          DesiredCount 3
60          TFBot
61          {
62              Template T_TFBot_Spy
63          }
64      }
65
66      // Wave 2 sydney snipers
67      Mission
68      {
69          Objective Sniper
70          InitialCooldown 120
71          Where spawnbot_mission_sniper
72          BeginAtWave 1
73          RunForThisManyWaves 1
74          CooldownTime 60
75          DesiredCount 2
76          TFBot
77          {
78              Template T_TFBot_Sniper_Sydney_Sleeper
79          }
80      }

```

You will find that the syntax for pop files can sometimes become very wordy and verbose. The more complicated your mission design is, the more verbose the pop file will be. This has no impact on server performance or anything like that, but it will make your pop file development a bit longer and tedious. Pop files are internally keyvalue files, and are parsed by Valve's keyvalues parser, so describing data in keyvalues form can sometimes be very lengthy and verbose.

The missions have been added, so now we can start building the actual waves. The order in which waves are declared in the pop file is the order in which they will appear. The first wave block is thus wave 1, the second wave block is wave 2, and so on. Here is a section of wave 1 (it's currently blank):

```

80      }
81
82      // Wave 1
83      Wave
84      {
85          StartWaveOutput
86          {
87              Target wave_start_relay
88              Action Trigger
89          }
90          DoneOutput
91          {
92              Target wave_finished_relay
93              Action trigger
94          }
95      }
96
97  }

```

The population manager emits *outputs* similar to map entity I/O (input/output).

The **StartWaveOutput** is fired when the wave is first loaded up. The **DoneOutput** is fired when the wave is completed. There's also an **InitWaveOutput** that some maps may use (like manhattan).

More often than not, you blindly copy and paste this section from a pop file that came with the map into your pop file. Otherwise, you have to decompile the map and inspect its entity work to figure out what to put in there (if anything), which can be annoying and time-consuming.

After you put that preamble in, you can start constructing the meat of your wave. A wave is broken up into multiple subwaves, or wavespawns. In the outline, each bullet (or block from the flow chart) is a wavespawn. You can only spawn one type of robot in a wavespawn (with squads and random choice being exceptions), so your wave is essentially a mishmash of several wavespawns put together.

A wavespawn can look something like this:

```

96      WaveSpawn
97      {
98          Name "wave01a"
99          Where spawnbot
100         TotalCount 32
101         MaxActive 12
102         SpawnCount 4
103         WaitBeforeStarting 1
104         WaitBetweenSpawns 1
105         TotalCurrency 100
106         TFBot
107         {
108             Template T_TFBot_Heavyweapons_Fist
109         }
110     }

```


The **Name** of a wavespawn is used for other wavespawns to reference to it. In general, you want to give every wavespawn a name except for the ones marked as *Support* (more on this later). If you do not give a wavespawn a name, it will still work, but you cannot link other wavespawns to it.

The **Where** works just like it did in the Mission block – it specifies the name of the spawnpoint (*info_player_teamspawn*) the bots in this wavespawn will spawn from. If the map has multiple spawn areas like bottom/top or left/right spawns, use the name of the *info_player_teamspawn* that is located in that area to spawn bots there. **You must provide a valid spawnpoint or else the bots will not spawn.**

The **TotalCount** is the number of bots in that wavespawn. The wavespawn will continue to spawn bots until the TotalCount value is reached, at which point the wavespawn is then disabled (unless if it is marked as Support 1 – more on this later). The TotalCount values are what appear on the wave HUD. Here this value is set to 32, so a total of 32 bots will spawn from this wavespawn.

The **MaxActive** is the maximum number of bots from that wavespawn that can be alive on the map at any given point in time. If the MaxActive number of bots is alive on the map, the wavespawn will not spawn more bots in until some of them are killed. This is used to throttle the number of bots alive at once. Setting this value is key to preventing your mission from being too easy or too hard/spammy. Here the value is 12, which means no more than 12 bots from this wavespawn can be alive simultaneously.

The **SpawnCount** is the number of bots that will spawn every time the wavespawn chooses to spawn more robots in. Here the value is 4, so 4 bots will spawn at a time every time the wavespawn spawns more robots. If spawning the SpawnCount number of robots would make the number of robots alive exceed the MaxActive value, the wavespawn will wait until some of those robots are killed before spawning more. In this case, if 12 bots are already alive, then players must kill at least 4 of them before the wavespawn spawns in 4 more bots, or else the wavespawn would break the MaxActive limit.

The **WaitBeforeStarting** is the number of seconds a wavespawn will wait before it spawns its first set of robots. It is commonly used to give a breather between two wavespawns connected in series. Here the value is set to 1, so the wavespawn will wait 1 second before it spawns its first set of robots (4 bots in this case, since the SpawnCount is 4).

The **WaitBetweenSpawns** is the number of seconds a wavespawn will wait after spawning a set of robots before spawning more robots. This acts as a breather between bot spawns. Setting this value properly is key to pacing your mission correctly. Here the value is set to 1, so after a wavespawn spawns robots (4 bots in this case, since the SpawnCount is 4), it will wait 1 second before spawning 4 more robots. If, after waiting out the WaitBetweenSpawns, spawning more robots would break the MaxActive limit, the wavespawn will wait longer than its WaitBetweenSpawns value until the number of bots alive decreases enough for it to spawn more robots.

The **TotalCurrency** is the total amount of money the bots from this wavespawn will drop. This value is 100, so the 32 (*TotalCount*) bots will drop a total of \$100 of money when they die. This is split more-or-less evenly across each robot that spawns into the map.

The **TFBot** section has the robot template (the type of robot) that will be spawned in this wavespawn. Here it's referencing a steel gauntlet melee heavy. Templates will be discussed more in detail later.

Another example of what a wavespawn can look like:

```

112 |
113 | WaveSpawn
114 | {
115 |     Name "wave01b"
116 |     WaitForAllDead "wave01a"
117 |     Where spawnbot
118 |     TotalCount 4
119 |     MaxActive 2
120 |     SpawnCount 1
121 |     WaitBeforeStarting 30
122 |     WaitBetweenSpawns 15
123 |     TotalCurrency 200
124 |     TFBot
125 |     {
126 |         Template T_TFBot_Giant_Heavyweapons_Deflector
127 |     }

```

WaitForAllDead links this wavespawn to a previous wavespawn. This wavespawn will not start until the previous wavespawn's robots are all dead. In this case, it waits for "wave01a" to be dead. This wavespawn will not spawn giant deflector heavies until all the steel gauntlet heavies from the previous wavespawn have been killed.

Here is another wavespawn:

```

129 |
130 | WaveSpawn
131 | {
132 |     Name "wave01c"
133 |     WaitForAllSpawned "wave01b"
134 |     Where spawnbot
135 |     TotalCount 30
136 |     MaxActive 9
137 |     SpawnCount 3
138 |     WaitBeforeStarting 5
139 |     WaitBetweenSpawns 5
140 |     TotalCurrency 100
141 |     Support 1
142 |     Squad
143 |     {
144 |         FormationSize 360
145 |         ShouldPreserveSquad 1
146 |         TFBot
147 |         {
148 |             Template T_TFBot_Sniper_Huntsman
149 |         }
150 |         TFBot
151 |         {
152 |             Template T_TFBot_Medic
153 |         }
154 |         TFBot
155 |         {
156 |             Template T_TFBot_Medic
157 |         }
158 |     }

```

WaitForAllSpawned behaves the same as **WaitForAllDead** except for one small difference: Instead of waiting for the previous wavespawns' robots to be all dead before starting, it waits for the previous wavespawns' robots to be all spawned in before starting. In this case, it waits for the giant deflector heavies in "wave01b" to finish spawning before it spawns the squad of robots.

If this was *WaitForAllDead*, then this wavespawn will start after the last giant heavy is killed. However, since this uses *WaitForAllSpawned*, this wavespawn will start after the last giant heavy spawns, since the previous wavespawn has finished spawning all of its giant heavies in and has no more robots to spawn.

Support is a special property. If it's set to 1, that means once this wavespawn begins spawning robots, it will never stop spawning bots for the rest of the wave. It is not mandatory to kill all of these robots, but they are still capable of killing players, moving the bomb, deploying the bomb, etc.

Robots in **Support 1** (also known as “infinite support” or “inf support” for short) serve to be a nuisance to players. These robots should not make up a large chunk of the main robot horde, since players do not like spending a majority of their time fighting the infinite support robots. The support robots appear on the right side of the wave HUD above the word “Support” and do not count towards the wave's progress. The robots from this wavespawn will drop money in the same manner as non-support wavespawns do, but once the *TotalCurrency* amount of money is dropped, additional robots will not drop money.

There is another value that can be passed into Support, known as **Support Limited**. If the word “*Limited*” is provided, this means the wavespawn acts both as a normal wavespawn and an inf support wavespawn. The robots will appear in the support section of the HUD (like inf support wavespawns), but they will only spawn up to the specified *TotalCount* number of robots (like normal wavespawns). Like inf support wavespawns, it is not mandatory to destroy all these robots to end the wave. To put it simply, Support Limited behaves like Support 1 except that it doesn't spawn unlimited bots forever.

The **Squad** block allows you to bundle robots together into a squad formation. Squads have one robot designated as the squad leader, and the other robots are the squad members. The first TFBot (robot template) in the squad is the squad leader; the rest are squad members. In this case, the squad has 1 huntsman sniper and 2 medics in that order, so the squad leader is a huntsman sniper and squad members are the two medics. Note that you need to add a TFBot for every member you want to add to the squad. We needed two medic TFBot to tell the server that there are 2 medics in each squad.

The **FormationSize** in the squad tweaks how closely clustered or spread apart the squad members are from the squad leader. The larger this number is, the farther away they are from the leader. Similarly, the smaller this number is, the closer they will be to the leader. **This value is often omitted in squads.**

The **ShouldPreserveSquad** decides whether a squad should disintegrate into lone bots or still remain together as a squad if the squad leader is killed. If the squad leader is killed, naturally the squad is dissolved and all the squad members leave the squad – they become lone bots as if they spawned from a normal wavespawn. However, if ShouldPreserveSquad is set to 1, then the bots will still remain in a squad formation even if the leader is no longer alive. **This value is often omitted in squads.**

For squads, the *TotalCount* **must** be evenly divisible by the number of robots in the squad (the squad size), or else the wave hud will break or incorrectly report the number of bots remaining. The *MaxActive* and *SpawnCount* do not have to be evenly divisible by the squad size, but for best practice pick numbers that are evenly divisible by the squad size to avoid bugs.

Here's another wavespawn:

```

160 WaveSpawn
161 {
162     Name "wave01d"
163     Where spawnbot
164     TotalCount 10
165     MaxActive 2
166     SpawnCount 1
167     WaitBeforeStarting 30
168     WaitBetweenSpawns 15
169     TotalCurrency 350
170     RandomChoice
171     {
172         TFBot
173         {
174             Template T_TFBot_Giant_Demo_RapidFire
175         }
176         TFBot
177         {
178             Template T_TFBot_Giant_Soldier_Spammer
179         }
180         TFBot
181         {
182             Template T_TFBot_Giant_Soldier_Spammer
183         }
184     }
185 }

```

This wavespawn features **RandomChoice**. Every time this wavespawn runs, it will pick a random robot from the given list of robot templates (TFBot). You can set the probability of a robot template being picked by adding or removing TFBot sections from within the RandomChoice.

In this wavespawn, we have 1 giant rapidfire demoman and 2 giant spammer soldiers, so there is a 1 in 3 chance (33%) this wavespawn will spawn a giant demoman and a 2 in 3 chance (67%) this wavespawn will spawn a giant soldier.

You **cannot** nest *Squads* inside RandomChoice (i.e. make it pick a random squad) or RandomChoice inside Squads (i.e. make it pick a random squad member or leader each time). The server will refuse to load that section of the pop file if it detects Squads or RandomChoice inside each other.

Lastly, here's a tank wavespawn:

```

187 WaveSpawn
188 {
189     WaitForAllDead "wave01d"
190     TotalCount 1
191     WaitBeforeStarting 25
192     TotalCurrency 300
193     FirstSpawnOutput
194     {
195         Target boss_spawn_relay
196         Action Trigger
197     }
198     Tank
199     {
200         Name "tankboss"
201         Health 40000
202         Speed 75
203         StartingPathTrackNode "boss_path_a1"
204         Skin 1
205         OnKilledOutput
206         {
207             Target boss_dead_relay
208             Action Trigger
209         }
210         OnBombDroppedOutput
211         {
212             Target boss_deploy_relay
213             Action Trigger
214         }
215     }
216 }

```

We have seen the first 4 properties of the wavespawn before. The **FirstSpawnOutput** section allows the wavespawn to trigger entity work when the tank first spawns into the map. The **Target** is the name of the entity, and **Action** is the input to send to the entity (similar to *StartWaveOutput* and *DoneOutput* for waves). Usually these reference to *logic_relay* entities on the map and send the input *Trigger*. Usually you just copy and paste this from a pop file that came with the map.

The **Tank** section creates a tank, similar to how the *TFBot* section creates a robot.

The **Name** gives the tank a name. This is not used meaningfully elsewhere in the pop file, but it may have some special meaning in the map. More often than not, the tank's name doesn't mean anything, so feel free to name it as whatever or even omit this property.

The **Health** sets the amount of health for the tank. This is rather self-explanatory.

The **Speed** sets the speed (in HU/s) the tank travels at. Do not set this value too high or else the tank will glide around the map and get stuck into world geometry. Usually you want to leave this at 75.

The **StartingPathTrackNode** specifies which path the tank should take. More strictly speaking, it specifies which *path_track* entity the tank should spawn on. You can either find this information from the pop files that ship with the map or decompile the map and inspect the *path_track* connections on hammer.

The **Skin** sets the skin on the tank. If set to 1, the tank will use the final skin with the black and white stripes. Do not specify this value if you want the standard tank skin on the tank.

The **OnKilledOutput** sends an input to an entity on the map when the tank is killed. Just copy and paste this from a pop file that came with the map.

The **OnBombDroppedOutput** sends an input to an entity on the map when the tank deploys its bomb (this entity is usually a *logic_relay* that forces victory for the robots team). Again, just copy and paste this from a pop file that came with the map.

The last important thing about a pop file are the robot templates. So far, we have seen robot templates named like **T_TFBot_Giant_Heavyweapons_Deflector**, but where is this information actually stored?

```
T_TFBot_Giant_Heavyweapons_Deflector
{
    Name "Giant Deflector Heavy"
    Class Heavyweapons
    Skill Expert
    Health 5000
    ClassIcon heavy_deflector
    Item "Deflector"
    Item "The U-clank-a"
    Attributes MiniBoss
    WeaponRestrictions PrimaryOnly
    MaxVisionRange 1200
    ItemAttributes
    {
        ItemName "Deflector"
        "attack projectiles" 1
        "damage bonus" 1.5
    }
    CharacterAttributes
    {
        "airblast vulnerability multiplier" 0.3
        "damage force reduction" 0.3
        "move speed bonus" 0.5
        "override footstep sound set" 2
    }
}
```

The templates for Valve robots are stored inside **robot_standard.pop**, **robot_giant.pop**, and **robot_gatebot.pop**. Have a peek at them to see all the robot template definitions. You can find them inside `tf_scripts_dir.vpk` or from downloading [this file](#) of all the Valve-made pop files.

The template properties will be explained later, but the two important sections to take note of are *ItemAttributes* and *CharacterAttributes*. Every player, bot and weapon entity on the server has a table that can house up to 15 attributes. When you buy upgrades at the upgrades station, those upgrades are attributes that are added to the attributes table on your player entity or your weapon entities. Similarly, the pop file can add attributes to these tables for the robot or the robot's weapon themselves.

The **ItemAttributes** adds attributes to a robot's weapon. In the above template, 2 attributes are added, such as a damage bonus. The **ItemName** specifies the name of the item that should receive those attributes. You can use an *ItemAttributes* block for each weapon as you wish, but since robots usually use only one weapon (primary for most, secondary for medics, melee for spy, or they are weapon restricted), you will usually use only one *ItemAttributes* block in a template.

The **CharacterAttributes** adds attributes to the robot itself. In the above template, 4 attributes are added.

Generally, resistances and player-based effects (like move speed, jump height, etc) should go into *CharacterAttributes*, and weapon-specific attributes should go into *ItemAttributes*. However, it is more-or-less safe to just throw everything into *CharacterAttributes* if you want, unless you somehow reach the 15 attribute limit (in which case, you will need to move some of those attributes to the weapons).

You can find all the attributes in the game from `items_game.txt`. Note that not all attributes are functional and some of them will require trial and error to figure out how they work, if their name isn't too obvious. Some attributes only work on some weapon types and not on others.

Gatebot templates are more complicated and messier:

```
T_TFGateBot_Scout_FAN_Crit
{
    Name "Force-A-Nature Scout"
    Class Scout
    ClassIcon scout_fan
    EventChangeAttributes
    {
        Default
        {
            Skill Expert
            Item "MvM GateBot Light Scout"
            Item "The Force-a-Nature"
            Attributes AlwaysCrit
            Attributes IgnoreFlag
            BehaviorModifiers Push
            MaxVisionRange 750
            Tag bot_gatebot
            Tag nav_prefer_gate1_flank
            ItemAttributes
            {
                ItemName "The Force-a-Nature"
                "damage penalty" 0.65
                "faster reload rate" 1.5
                "scattergun knockback mult" 2
            }
        }
        RevertGateBotsBehavior
        {
            Skill Expert
            Item "MvM GateBot Light Scout"
            Item "The Force-a-Nature"
            Attributes AlwaysCrit
            MaxVisionRange 500
            ItemAttributes
            {
                ItemName "MvM GateBot Light Scout"
                "item style override" 1
            }
            ItemAttributes
            {
                ItemName "The Force-a-Nature"
                "damage penalty" 0.65
                "faster reload rate" 1.5
                "scattergun knockback mult" 1.7
            }
        }
    }
}
```

Properties of the robot that cannot be changed on the fly, such as the robot's name and class, are entered first. Then an **EventChangeAttributes** block is added, which contains 2 sub-blocks: **Default** and **RevertGateBotsBehavior**. This is essentially 2 bot templates in one that can be flip-flopped between.

The **Default** section contains bot information and characteristics (i.e. it's the bot template) when the bots are on their gatebot AI mode (they don't pick up bombs and run towards a gate).

The **RevertGateBotsBehavior** section contains bot information when the bots have successfully captured all the gates on the map and disable their gatebot AI mode (they behave like normal bots).

Essentially, the *Default* section is the bot template during the bot's gatebot AI mode and the *RevertGateBotsBehavior* section is the bot template after the bot disables its gatebot AI mode. They both share the same properties defined outside the *EventChangeAttributes* section.

Gatebot templates can crash the game if they have invalid syntax, so be careful when working with them.

Operation Titanium Tank: A Guide to MvM Wave Writing

Robot templates can be define in three ways. The first way is to reference the template name, as we have seen earlier:

```
TFBot
{
    Template T_TFBot_Heavyweapons_Fist
}
```

Another way is to inline the template inside the TFBot section directly, without referencing any premade templates. This is not recommended unless this robot is featured in one wavespawn only, or else you will have to copy and paste the bot information every time you want to use it, which will bloat your pop file. It's best to define a template for a robot you plan on using more than once.

```
TFBot
{
    Class Heavyweapons
    Skill Expert
    Attributes AlwaysCrit
    ItemAttributes
    {
        ItemName "TF_WEAPON_MINIGUN"
        "damage bonus" 1.5
    }
}
```

The third way is to use an existing template but add on to or override some of its properties. The two TFBot sections in the squad below show this in action:

```
Squad
{
    TFBot
    {
        Template T_TFBot_Giant_Heavyweapons
        Tag nav_prefer_flank_right
    }
    TFBot
    {
        Template T_TFBot_Medic_QuickUber
        ItemAttributes
        {
            ItemName "TF_WEAPON_MEDIGUN"
            "uber duration bonus" 4
        }
    }
}
```

The first TFBot section adds a tag to the stock giant heavy template. All other properties of the robot are taken (inherited) from the giant heavy template. This enables you to not have to completely clone a robot's template only to add or change one thing about it (unlike the spy Mission example we did earlier).

The second TFBot section overrides the attributes on the medic's medigun. The template has the uber duration bonus attribute set to -3, but here it is overridden with a value of 4.

Taken from the server binary (*server_srv.so*), here is a full list of functional properties you can use on pop files (defunct properties are not included here). Properties that start with an asterisk * don't take a single value, but are outputs emitted by the population manager that can send an input to a map entity (they need a *Target* and an *Action* to be provided).

>>> *Wave*:

***StartWaveOutput** – Called when the wave has been loaded.

***InitWaveOutput** – Called right before StartWaveOutput.

***DoneOutput** – Called when the wave has been completed.

>>> *WaveSpawn*:

TotalCount – The number of bots to spawn in this wavespawn (this is ignored if *Support* is set to 1).

MaxActive – The maximum number of bots from this wavespawn that can be alive simultaneously.

SpawnCount – The number of bots to spawn in simultaneously every time the wavespawn spawns bots.

WaitBeforeStarting – The number of seconds to wait (time delay) before starting this wavespawn after it has been given permission to start spawning (e.g. prior wavespawns have finished spawning robots).

WaitBetweenSpawns – Number of seconds to wait after the wavespawn has spawned in robots before it can spawn more robots (provided the *MaxActive* isn't reached).

WaitBetweenSpawnsAfterDeath – If set to 1, the wavespawn will only spawn robots every time the previous batch is dead.

FirstSpawnWarningSound – Plays a sound to all clients when the first bot in this wavespawn spawns in.

***FirstSpawnOutput** – Called when the first bot of the wavespawn spawns in.

LastSpawnWarningSound – Plays a sound to all clients when the last bot in this wavespawn spawns in.

***LastSpawnOutput** – Called when the last bot of the wavespawn spawns in.

TotalCurrency – The total amount of money this wavespawn's robots will drop.

Name – The name of the wavespawn.

Where – Name of the info_player_teamspawn

WaitForAllSpawned – The wavespawn to wait to finish spawning bots before starting this wavespawn.

WaitForAllDead – The wavespawn to wait for its bots to be killed before starting this wavespawn.

Support – Marks a wavespawn as support (can use values "1" or "Limited").

RandomSpawn – If set to 1, the wavespawn spawns bots on random spawn points on the map. You will have to specify multiple spawn points (i.e. specify "Where" multiple times) to use this properly.

The most common properties you will use are: **Name**, **Where**, **TotalCount**, **MaxActive**, **SpawnCount**, **WaitBeforeStarting**, **WaitBetweenSpawns**, **TotalCurrency**, **WaitForAllSpawned**, **WaitForAllDead**, and on occasion, **Support**. The others are rarely or sometimes never used in a majority of pop files.

>>> *WaveSchedule:*

StartingCurrency – The amount of money players start the mission with.

RespawnWaveTime – The number of seconds players must wait before they can respawn into the map every time they are killed.

FixedRespawnWaveTime – If set to 1, then the respawn time for players is set to the value specified by RespawnWaveTime. Otherwise, the respawn time increases by 2 seconds per wave that is completed.

AddSentryBusterWhenDamageDealtExceeds – Sets the damage threshold (default 3000) on how much damage a sentry gun must deal to the robots before a sentry buster spawns to chase that sentry gun.

AddSentryBusterWhenKillCountExceeds – Sets the kill threshold (default 15) on the number of robots a sentry gun must kill before a sentry buster spawns to chase that sentry gun.

CanBotsAttackWhileInSpawnRoom – Allows or forbids bots from attacking while in their spawn area.

IsEndless – If set to 1, the mission will run using the hidden endless MvM mode.

Advanced – If set to 1, the mission will be marked as a difficult mission for achievements and the like.

>>> *Mission:*

Objective – The objective AI the bot should use.

InitialCooldown – The initial time delay before this objective's robots are allowed to spawn in. (Works identically to *WaitBeforeStarting* for wavespawns).

CooldownTime – The number of seconds to wait between objective robot spawns. (Works identically to *WaitBetweenSpawns* for wavespawns.)

BeginAtWave – The wave number that these objective bots should be featured in.

RunForThisManyWaves – The number of waves this objective bot should be featured in, starting from BeginAtWave. The ending wave number is calculated from $\text{BeginAtWave} + \text{RunForThisManyWaves} - 1$.

DesiredCount – The number of bots to spawn in each time the mission spawns bots in. (Works identically to *SpawnCount* for wavespawns.)

>>> Valid values for *Objective*:

Sniper – The bot will use the sniper AI. They will find sniping spots on the map and attempt to snipe players from those locations.

Spy – The bot will use the spy AI. They will spawn around hidden corners and the like (as determined by the map's nav mesh) to ambush and attack players.

Engineer – The bot will use the engineer AI. They will spawn at engineer hint entities on the map and place buildings on the sentry and teleporter hint entities (if they exist on the map).

DestroySentries – The bot will use the sentry buster AI. They will find a sentry gun dealing plenty of damage to the bot horde, run up to them and suicide to take out the offending sentry gun.

>>> *Squad:*

FormationSize – Sets how far apart or close together the squad members are to its leader.

ShouldPreserveSquad – If set to 1, the squad will maintain its formation even if its leader is killed.

>>> *Bot Templates:*

Name – Sets the name of the bot. This name will appear on the killfeed when the bot kills or is killed.

Class – The robot's class (out of the 9 TF2 classes).

Skill – Sets the bot AI level.

Health – The amount of health to set on the robot.

ClassIcon – The name of the icon to use on the wave HUD to represent this robot.

Scale – Sets the size of the robot (giants by default are scaled to 1.75). Do not set this value too high or else bots may become stuck around corridors or other world geometry not designed for large bots.

WeaponRestrictions – Sets the weapon slot of the weapon the bot is only allowed to use in combat. If unspecified, most classes will use their primary, medics will use their secondary, spies will use melee.

BehaviorModifiers – Changes the bot's behavior.

Item – Grants the bot a weapon or cosmetic item. Note that unlike weapons, bots ignore class restrictions on cosmetics, so it is possible to put a heavy's hat on, say, a demoman bot.

Attributes – Adds special attributes to the bot (not the same as attributes from *items_game.txt*).

MaxVisionRange – The maximum distance radius (in HU) that the bots can see players in. Outside of this range, the bots will not notice players.

ItemAttributes – Adds attributes (from *items_game.txt*) to the bot's item. This can be specified multiple times to add attributes to multiple items (including cosmetics). The limit is 15 attributes.

CharacterAttributes – Adds attributes (from *items_game.txt*) to the bot itself. The limit is 15 attributes.

TeleportWhere – **Used for engineer bots only.** Just like *Where* in *wavespawns*, this accepts the names of spawn points (*info_player_teamspawn*). The spawn points listed in *TeleportWhere* on the engineer specify which spawns will spawn bots from the engineer's teleporter instead of on the map's spawn point.

AutoJumpMin – The minimum cooldown time before the bot will jump. The bot must possess the *AutoJump* attribute to use this feature.

AutoJumpMax – The maximum cooldown time before the bot will jump. The bot must possess the *AutoJump* attribute to use this feature.

Valid *Skill* values (from easiest to hardest): **Easy, Normal, Hard, Expert**

Valid *WeaponRestrictions* values: **PrimaryOnly, SecondaryOnly, MeleeOnly**

Valid *Class* values: **Scout, Soldier, Pyro, Demoman, Heavyweapons, Engineer, Medic, Sniper, Spy**

>>> Valid *BehaviorModifiers* values:

Mobber – The bot will pick a player and constantly chase them until either the player or the bot is killed.

Push – The bots will initially ignore the bomb and make a run for the hatch first before running back to the bomb. This is often used for flanking and ambushing bots to sneak up behind the players.

>>> Valid *Attributes* values:

Aggressive – Acts the same as *BehaviorModifiers Mobber*.

SupressFire – The bot will not shoot its weapon.

DisableDodge – The bots will not attempt to dodge incoming projectiles from players.

SpawnWithFullCharge – The bot will spawn with a full charge on all meters on its weapons. This includes phlog charge, banner charge, medigun ubercharge, medic shield charge, etc.

AlwaysCrit – The bot's weapons are always critboosted. Their icon will also have a sky blue flashing border on the wave HUD.

IgnoreEnemies – The bots will act blindly towards players and only perform the map objective.

HoldFireUntilFullReload – When the bot's weapon clip is empty, the bot will not fire its weapon until its fully reloaded.

AlwaysFireWeapon – The bot will always fire its weapon (as if it's holding M1 down forever).

TeleportToHint – Used for engineers only. The engineer will teleport on its hint entity instead of spawning from a map spawn point and walking all the way to its hint entity.

MiniBoss – Marks the bot as a giant. Their icon will appear with a red background on the wave HUD, their heads will be smaller than their body, and spies cannot one-hit-kill them with a backstab.

UseBossHealthBar – Displays a health bar of the robot's health for all the players to see, similar to the health bar tanks display when they spawn on the map.

IgnoreFlag – The bot will ignore the bomb and only harass players or follow specific routes on the map.

AutoJump – The bot will jump randomly. You will need to provide an AutoJumpMin and AutoJumpMax to the bot template if you use this attribute.

AirChargeOnly – Used for demoman bots with a shield only. The bot will charge only while airborne.

VaccinatorBullets – Used for vaccinator medics only. The medic will use the bullet vaccinator effect (blue effect) on the vaccinator medigun.

VaccinatorBlast – Used for vaccinator medics only. The medic will use the blast vaccinator effect (green effect) on the vaccinator medigun.

VaccinatorFire – Used for vaccinator medics only. The medic will use the fire vaccinator effect (red effect) on the vaccinator medigun.

BulletImmune – The bot is invincible from bullet damage.

BlastImmune – The bot is invincible from blast damage.

FireImmune – The bot is invincible from fire damage.

Parachute – The bot will attempt to parachute down while airborne. This is commonly used on B.A.S.E. Jumper soldiers.

ProjectileShield – Used for medics using a medigun only. The bot will deploy the medic's projectile shield in front of its healing target when its shield meter is fully charged. You will need to attach the "generate rage on heal" attribute to the medigun for it to use the medic's shield. Set this attribute to 1 to use the small shield, 2 to use the large shield (works similar to the shield upgrade). To change the duration of the shield, use the "increase buff duration" attribute.

A note about class icons:

The *ClassIcon* property has a string X in it. When the client receives this information from the server, it searches for a *leaderboard_class_X.vmt* file inside *tf/materials/hud* (or other mounted folders). If "heavy_deflector" is used (like in *T_TFBot_Giant_Heavyweapons_Deflector*), the client searches for a *leaderboard_class_heavy_deflector.vmt* file to load. Vmt (valve map texture) files typically have an accompanying vtf (valve texture file) file with it, and the vtf file itself is referenced inside the vmt file.

If you make your own custom bot icon (64 x 64 pixel square image) for a custom robot, and you write "*ClassIcon robot_launcher*" in its template on the pop file, make sure the vmt file of your icon is *leaderboard_class_robot_launcher.vmt* and that the vmt file references the correct vtf file to load.

>>> Tank:

Health – The amount of health the tank should have. Pretty self-explanatory.

Speed – How fast the tank moves. Don't set this number too high or else wild behavior may occur.

Name – The name to assign to the tank.

Skin – The skin to use on the tank (values are 0 or 1).

StartingPathTrackNode – The name of the path_track the tank should spawn on.

***OnKilledOutput** – Called when the tank is destroyed.

***OnBombDroppedOutput** – Called when the tank deploys its bomb.

Operation Titanium Tank: A Guide to MvM Wave Writing

Now that we have discussed most of the features in pop files, it's time to create the two wave mission we have outlined earlier. We will discuss how to construct the first wave only and leave it as an exercise for you to construct the second wave on your own. The full pop file is provided at the end of the tutorial.

With the global properties, missions, and wave 1 preamble, your pop file should currently look like this:

```
1 // Imports bot templates from other pop files (Valve
2 #base robot_giant.pop
3 #base robot_standard.pop
4
5 WaveSchedule
6 {
7     // Init
8     StartingCurrency 1500
9     RespawnWaveTime 6
10    CanBotsAttackWhileInSpawnRoom no
11
12    // Bot templates
13    Templates
14    {
15    }
16
17    // Sentry buster mission
18    Mission
19    {
20    {
21        Objective DestroySentries
22        InitialCooldown 20
23        Where spawnbot
24        BeginAtWave 1
25        RunForThisManyWaves 9
26        CooldownTime 20
27        DesiredCount 1
28        TFBot
29        {
30            Template T_TFBot_SentryBuster
31        }
32    }
33
34    // Wave 1 spies
35    Mission
36    {
37    {
38        Objective Spy
39        InitialCooldown 90
40        Where spawnbot_mission_spy
41        BeginAtWave 1
42        RunForThisManyWaves 2
43        CooldownTime 60
44        DesiredCount 3
45        TFBot
46        {
47            Template T_TFBot_Spy
48        }
49    }
50
51    // Wave 2 sydney snipers
52    Mission
53    {
54    {
55        Objective Sniper
56        InitialCooldown 120
57        Where spawnbot_mission_sniper
58        BeginAtWave 1
59        RunForThisManyWaves 1
60        CooldownTime 60
61        DesiredCount 2
62        TFBot
63        {
64            Template T_TFBot_Sniper_Sydney_Sleeper
65        }
66    }
67
68    // Wave 1
69    Wave
70    {
71    {
72        StartWaveOutput
73        {
74            Target wave_start_relay
75            Action Trigger
76        }
77        DoneOutput
78        {
79            Target wave_finished_relay
80            Action trigger
81        }
82    }
83    }
```

Our outline for wave 1 is: (see page 2 for the graphical outline)

- 1) Wave 1 (\$800 total)
 - a. (\$100) 30 scattergun scouts
 - b. (\$100) 100 demoknights (sporadically across the whole wave)
 - c. (\$200) 2 giant pyros with 4 uber medics each
 - d. (\$100) Infinite support sandman scouts (after scattergun scouts die)
 - e. (\$100) 35 crit soldiers (after the giant pyros finish spawning)
 - f. (\$200) 2 giant heavies (after giant pyros die)

The objective support bots have been omitted since we have put them in the Mission section already. The first thing we will do is create the first wavespawn, which consists of 30 scattergun scouts. Some of the properties (*TotalCount*, *TotalCurrency*, *WaitForAllDead/Spawned*, *Support*) are specified in the outline. Others (*Where*, *MaxActive*, *SpawnCount*, *WaitBeforeStarting*, *WaitBetweenSpawns*) are not mentioned in the outline. Maybe on your outline you have them specified, but this outline does not.

For the unspecified values, you will have to use some common sense and intuition to decide on sane numbers to use. After you enter those values in, test your pop file with people and tweak those values accordingly. There are no hard or fast rules on what values to specify on each of those properties; you have to look at the wave as a whole and decide if the pacing is too fast/slow, bots are too strong/weak, etc and adjust the wavespawn(s) accordingly. Sometimes it may be changing a couple of numbers, other times it may involve tweaking or swapping out bot templates, sometimes wavespawns may be moved around, other times a whole wavespawn may be added or removed from the wave.

Here is the first wavespawn for this wave. I called it *wave1a* since it's in wave 1 and it's the first wavespawn of wave 1. You can call your wavespawns whatever you want but if you stick to some convention that works best for you, it will help you down the road when you tweak your pop file.

```
// 30 scattergun scouts
WaveSpawn
{
    Name "wave1a"
    Where spawnbot
    TotalCount 30
    MaxActive 6
    SpawnCount 2
    WaitBeforeStarting 0
    WaitBetweenSpawns 10
    TotalCurrency 100
    TFBot
    {
        Class Scout
        Skill Expert
    }
}
```

I set the *MaxActive* to be 6 since too many scattergun scouts can be overwhelming bullet spam. The *SpawnCount* is 2 so that not too many of them spawn at once, and I only allow 6 of them to be alive at once. The *WaitBeforeStarting* is 0 so that right when the wave starts there's no awkward pause of nothing spawning in. The *WaitBetweenSpawns* is 10 to avoid spamming the scattergun scouts in too much. These decisions are what will help you pick (sane) values to use on the other properties of the wavespawn.

Operation Titanium Tank: A Guide to MvM Wave Writing

The next wavespawn asks for 100 demoknights to spawn sporadically throughout the wave, so the demoknights should have a decent cooldown time between spawns but also spawn enough of them so they aren't merely fodder bots.

Since most bot wavespawns share very similar code, I can just copy and paste wave1a's wavespawn code right below it and change some numbers and the TFBot template to construct wavespawn wave1b, instead of typing out everything again. This copy-paste technique will allow you to build waves rather quickly.

My wave1b looks like:

```
// 100 demoknights (spawns sporadically throughout the wave)
WaveSpawn
{
    Name "wave1b"
    Where spawnbot
    TotalCount 100
    MaxActive 12
    SpawnCount 4
    WaitBeforeStarting 5
    WaitBetweenSpawns 15
    TotalCurrency 100
    TFBot
    {
        Template T_TFBot_Demoman_Knight
    }
}
```

Next, my outline asks for 2 giant pyros with 4 medics on each:

```
// 2 squads of 1 giant pyro and 4 uber medics on each
WaveSpawn
{
    Name "wave1c"
    Where spawnbot
    TotalCount 10
    MaxActive 10
    SpawnCount 5
    WaitBeforeStarting 30
    WaitBetweenSpawns 45
    TotalCurrency 200
    Squad
    {
        TFBot
        {
            Template T_TFBot_Giant_Pyro
        }
        TFBot
        {
            Template T_TFBot_Medic
        }
        TFBot
        {
            Template T_TFBot_Medic
        }
        TFBot
        {
            Template T_TFBot_Medic
        }
        TFBot
        {
            Template T_TFBot_Medic
        }
    }
}
```


I was still able to copy/paste most of the wavespawn, but instead of the TFBot at the bottom I had to put a Squad in. Otherwise this wavespawn took about 15 seconds to code up.

I needed 2 squads of 1 giant pyro and 4 uber medics, which means there are 10 robots total, so my TotalCount is 10. My MaxActive is 10 since I want to allow both squads to be out at once if the players are too slow to kill the first squad. My SpawnCount is 5 since there are 5 members in the squad. I set WaitBeforeStarting to be 30 since I didn't want to drop the giant squad immediately on the players (I wanted it to ramp up with the scatterguns, then the demoknights, and now the giant pyro). I set WaitBetweenSpawns to 45 since giant robots require more effort to take down so I don't want to overwhelm players by spawning them quickly after each other.

These are all design decisions I made in my mind when picking those values. These are not hard rules to good wave design; there are times where maybe you want to spawn both squads in at once (SpawnCount 10), like on opposite sides of the map or something. Maybe you don't want the second giant pyro squad to spawn until the first one is completely destroyed, so you would set MaxActive to 5 and lower the WaitBetweenSpawns. However, this is the thinking you need to do to fill in those values.

Now my 4th wavespawn wants to spawn infinite support sandman scouts, but only after the scatterguns are all dead. This wavespawn would look like:

```
// Infinite support sandman scouts (after the scatterguns all die)
WaveSpawn
{
    WaitForAllDead "wave1a"
    Where spawnbot
    TotalCount 25
    MaxActive 4
    SpawnCount 2
    WaitBeforeStarting 0
    WaitBetweenSpawns 5
    TotalCurrency 100
    Support 1
    TFBot
    {
        Template T_TFBot_Scout_Sandman_FastCharge
    }
}
```

The WaitForAllDead will wait for the bots on wave1a (the scattergun scouts) to die before this wavespawn starts spawning robots. For Support 1 wavespawns, spawn bots in slowly and in small quantities (set their MaxActive low as well), or else they will hog a significant number of server slots and annoy players since support bots spawn forever and don't count towards the overall wave progress.

There is no name given to this wavespawn since infinite support wavespawns cannot have any child wavespawns dependent on it (since they never are deactivated; they never finish spawning). If you give a name to this wavespawn and make other wavespawns wait for it to die or finish spawning, those dependent wavespawns will **never** run since the support wavespawn never stops running. For best practice, do not give support wavespawns a name to avoid hidden bugs with your waves.

The TotalCount decides how much money each robot will drop. Since it's set to 25, the first 25 robots in the support wavespawn will drop money at a rate of \$4 per robot (since the TotalCurrency is 100). After the first 25 robots spawn, additional robots will not drop any further money.

The next wavespawn asks for 35 crit soldiers to spawn after the giant pyros finish spawning. It doesn't want them to all die before the wavespawn starts – it just wants them to finish spawning. This means we will be using a WaitForAllSpawned here. This wavespawn looks like:

```
// Crit soldiers (after the last giant pyro squad spawns in)
WaveSpawn
{
    Name "wave1e"
    WaitForAllSpawned "wave1c"
    Where spawnbot
    TotalCount 35
    MaxActive 8
    SpawnCount 4
    WaitBeforeStarting 15
    WaitBetweenSpawns 10
    TotalCurrency 100
    TFBot
    {
        Class Soldier
        Skill Expert
        Attributes AlwaysCrit
    }
}
```

This wavespawn will wait for the last giant pyro squad to spawn in before starting. After that, it waits 15 seconds before spawning 4 crit soldiers at a time. It will spawn 4 crit soldiers every 10 seconds so long as spawning 4 crit soldiers into the map doesn't break the max limit of 8 crit soldiers alive at a time.

Our last wavespawn is to spawn 2 giant heavies after the giant pyros are dead. Unlike the crit soldier wavespawn, this one uses a `WaitForAllDead` since this wavespawn will not start until the giant pyro squads are destroyed. This wavespawn will look like this:

```
// Giant heavies (after the last giant pyro squad dies)
WaveSpawn
{
    Name "wave1f"
    WaitForAllDead "wave1c"
    Where spawnbot
    TotalCount 2
    MaxActive 1
    SpawnCount 1
    WaitBeforeStarting 0 // Start immediately after the giant pyro squad dies
    WaitBetweenSpawns 30
    TotalCurrency 200
    TFBot
    {
        Template T_TFBot_Giant_Heavyweapons
    }
}
```

The `MaxActive 1` will only allow 1 giant heavy to be alive at a time. The `WaitBeforeStarting` of 0 makes the giant heavy spawn immediately after the last giant pyro squad is destroyed.

After all these wavespawns are defeated, the wave is declared complete and players move on to the next wave (or the mission ends if there are no additional waves to move on to). There is an outline for wave 2 on page 3. As an exercise, try to build the wavespawns for wave 2 on your own. The solutions can be found [here](#), which includes the full pop file (the missions, wave 1, and wave 2). Do the coding yourself, and then compare your work to the solutions to assess how well you understand constructing pop files.

Testing:

So you outlined your waves and built the bot templates, missions, and wavespawns for all your waves. Your next step is to test your creation. Although MvM is meant to be played with a team of 5-6 players, it helps to do some basic testing on your end so that you avoid unnecessarily wasting players' time with problems you could have found out and fixed beforehand on your own.

Here are instructions to load your pop file in the game:

1. Navigate to your TF2 folder. You can find it by going to steam, right clicking **Team Fortress 2**, click **Properties**, go to the **Local Files** tab, and click **Browse Local Files...**
2. Click on the **tf** folder, then click on the **scripts** folder. You should see an **items_game.txt** file.
3. Create a folder called **population**. Put your pop file in there. You can put your pop file there and open it on notepad++ from there for quick updating.
4. Load TF2 and open the console (usually with the ` key).
5. Type "**map <mapname>**" where the *mapname* is the name of the MvM map you want to load. For example: **map mvm_dockyard_rc4**
6. Once the map loads, pick a class and spawn into the map. You must do this, since the population manager does not fully initialize until a player spawns into the map.
7. Go back to the console and type in "**tf_mvm_popfile <mission_name>**" where *mission_name* is the file name of your pop file. Example: **tf_mvm_popfile mvm_dockyard_rc4_cargo_collapse**

(You can omit the **mvm_dockyard_rc4** part and simply do **tf_mvm_popfile cargo_collapse** since the server will append the map name behind it automatically if it isn't specified.)
8. Your mission should load. Before you return to the game, check and make sure there are no errors reported to the console. If there are, you will need to fix them on your pop file.
9. (Optional) If there are no errors, enter the following into your console:
sv_cheats 1 ; tf_bot_flag_kill_on_touch 1 ; host_timescale 10

This will make the game run 10x faster and make bots suicide if they touch the bomb. If tanks spawn, however, you will need to destroy them yourself or use **ent_remove** on them. You can also kill all the bots on the map (so long as they aren't in their spawnroom) using **tf_bot_kill all**

Alternatively, use **currency_give** and **addcond** commands (with **sv_cheats 1**) to give yourself money, crits, uber, and other effects, and play the waves solo from start to finish. In any case, make sure all the bots spawn on your waves the way you want them to.

10. Test your mission with other players under normal vanilla MvM circumstances. This testing will give you an idea on the pace of your mission, how balanced it is, how long it takes to finish, and how fun players perceive your mission to be. Expect to change stuff like **WaitBeforeStarting**, **WaitBetweenSpawns**, **TotalCount**, **MaxActive**, **SpawnCount** often based on testing results.

Examples of syntax errors in the console:

```

] tf_mvm_popfile thiswillbreak
Unknown attribute 'WaverSpawn' in Wave definition.
Empty ambient_generic (ambient_generic) at -1454.34, -487.95, 585.00 <-- Unrelated to pop files, ignore this
Unknown attribute 'WaverSpawn' in Wave definition.

```

```
tff_mvm_popfile.thiswillbreak  
KeyValues Error: RecursiveLoadFromBuffer: got ] in key in file  
WaveSchedule, wave, WaveSpawn,  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*WaveSpawn*), (*TFBot*), (*attributes*), (*TFBot*), (*Skill*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*WaveSpawn*), (*TFBot*), (*attributes*), (*TFBot*), (*Skill*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*WaveSpawn*), (*TFBot*), (*attributes*), (*TFBot*), (*Skill*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*WaveSpawn*), (*TFBot*), (*attributes*), (*TFBot*), (*Skill*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*DoneOutput*), (*action*), (*TFBot*), (*attributes*), (*TFBot*), (*Skill*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*DoneOutput*), (*action*), (*TFBot*), (*attributes*), (*TFBot*), (*Skill*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*WaveSpawn*), (*TFBot*), (*template*), (*TFBot*), (*template*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*WaveSpawn*), (*TFBot*), (*template*), (*TFBot*), (*template*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*WaveSpawn*), (*TFBot*), (*template*), (*TFBot*), (*template*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*WaveSpawn*), (*TFBot*), (*template*), (*TFBot*), (*template*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*DoneOutput*), (*action*), (*TFBot*), (*template*), (*TFBot*), (*template*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*WaveSpawn*), (*TFBot*), (*skill*), (*OnBombDroppedOutput*), (*action*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*WaveSpawn*), (*TFBot*), (*skill*), (*OnBombDroppedOutput*), (*action*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*WaveSpawn*), (*TFBot*), (*skill*), (*OnBombDroppedOutput*), (*action*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*WaveSpawn*), (*TFBot*), (*skill*), (*OnBombDroppedOutput*), (*action*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*WaveSpawn*), (*Squad*), (*TFBot*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*WaveSpawn*), (*Squad*), (*TFBot*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*WaveSpawn*), (*Squad*), (*TFBot*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*WaveSpawn*), (*Squad*), (*TFBot*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*DoneOutput*), (*action*), (*Squad*), (*TFBot*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*DoneOutput*), (*action*), (*Squad*), (*TFBot*), (*ItemAttributes*),  
KeyValues Error: LoadFromBuffer: missing [ in file  
(*WaveSpawn*), (*Squad*), (*TFBot*), (*template*), (*ItemAttributes*),
```

```

KeyValues Error: LoadFromBuffer: missing { in file
(*WaveSpawn*), (*TFBot*), (*template*), (*OnBombDroppedOutput*), (*action*), (*ItemAttributes*),
Unknown attribute 'wave01a' in Wave definition.
Unknown attribute 'spawnbot' in Wave definition.
Unknown attribute '36' in Wave definition.
Unknown attribute '18' in Wave definition.
Unknown attribute '6' in Wave definition.
Unknown attribute '4' in Wave definition.
Unknown attribute '5' in Wave definition.
Unknown attribute '300' in Wave definition.
Unknown attribute '[' in Wave definition.
Unknown attribute '[' in Wave definition.
Unknown attribute 'scout' in Wave definition.
Unknown attribute 'Easy' in Wave definition.
Invalid populator 'TFBot'
Parse failed in CPopulationManager::Initialize for scripts/population/mvm_bigrock_thiswillbreak.pap
not be found. All items will be allowed.
KeyValues Error: RecursiveLoadFromBuffer: got } in key in file
WaveSchedule, wave, Easy, (*DoneOutput*),
KeyValues Error: LoadFromBuffer: missing { in file
(*WaveSchedule*), (*TFBot*), (*ItemAttributes*),

```

Common Syntax Errors:

The console spew may look scary but the cause of that is usually a minor error. Basically, the keyvalues parser misunderstood your pop file since you made a mistake in the syntax, and is thus going “wait what is this?” “this isn’t right?” “what am I looking at” and so on. Common culprits are:

- Forgetting an open or close brace:

<pre>WaveSpawn { Name "wave1a" Where spawnbot TotalCount 30 MaxActive 6 SpawnCount 2 WaitBeforeStarting 0 WaitBetweenSpawns 10 TotalCurrency 100 TFBot { Class Scout Skill Expert } }</pre>	<pre>WaveSpawn { Name "wave1a" Where spawnbot TotalCount 30 MaxActive 6 SpawnCount 2 WaitBeforeStarting 0 WaitBetweenSpawns 10 TotalCurrency 100 TFBot { Class Scout Skill Expert } }</pre>
---	---

- Forgetting to specify a value to a key or removed space between the key-value pair:

<pre>WaveSpawn { Name "wave1a" Where spawnbot TotalCount 30 MaxActive 6 SpawnCount 2 WaitBeforeStarting WaitBetweenSpawns 10 TotalCurrency 100 TFBot { Class Scout Skill Expert } }</pre>	<pre>WaveSpawn { Name "wave1a" Where spawnbot TotalCount 30 MaxActive 6 SpawnCount2 WaitBeforeStarting 0 WaitBetweenSpawns 10 TotalCurrency 100 TFBot { Class Scout Skill Expert } }</pre>
---	--

- Incorrectly spelling keywords:

<pre>WaveSpawn { Name "wave1a" Where spawnbot TotalCount 30 MaxActive 6 SpawCount 2 WaitBeforeStarting 0 WaitBetweenSpawns 10 TotalCurrency 100 TFBot { Class Scout Skill Expert } }</pre>	<pre>WavesSpawn { Name "wave1a" Where spawnbot TotalCount 30 MaxActive 6 SpawCount 2 WaitBeforeStarting 0 WaitBetweenSpawns 10 TotalCurrency 100 TFBot { Class Scout Skill Expert } }</pre>
--	---

- Too many open or closing braces

<pre>WaveSpawn { { Name "wave1a" Where spawnbot TotalCount 30 MaxActive 6 SpawnCount 2 WaitBeforeStarting 0 WaitBetweenSpawns 10 TotalCurrency 100 TFBot { { Class Scout Skill Expert } } } }</pre>	<pre>WaveSpawn { Name "wave1a" Where spawnbot TotalCount 30 MaxActive 6 SpawnCount 2 WaitBeforeStarting 0 WaitBetweenSpawns 10 TotalCurrency 100 TFBot { Class Scout Skill Expert } }</pre>
---	---

- Incorrect number of quotation marks. Quotation marks are mandatory for values that have more than one word (like "The Soda Popper" below).

<pre>WaveSpawn { Name "wave1a" Where spawnbot TotalCount 30 MaxActive 6 SpawnCount 2 WaitBeforeStarting 0 WaitBetweenSpawns 10 TotalCurrency 100 TFBot { { Class Scout Skill Expert Item "The Soda Popper" } } }</pre>	<pre>WaveSpawn { Name "wave1a" Where spawnbot TotalCount 30 MaxActive 6 SpawnCount 2 WaitBeforeStarting 0 WaitBetweenSpawns 10 TotalCurrency 100 TFBot { Class Scout Skill Expert Item The Soda Popper } }</pre>
--	--

- Invalid item or attribute names. They must use the **exact** spelling as listed in items_game.txt.

<pre>WaveSpawn { Name "wave1a" Where spawnbot TotalCount 30 MaxActive 6 SpawnCount 2 WaitBeforeStarting 0 WaitBetweenSpawns 10 TotalCurrency 100 TFBot { Class Scout Skill Expert CharacterAttributes { "move speed" 1.5 "increased jump height" 1.2 } } }</pre>	<pre>WaveSpawn { Name "wave1a" Where spawnbot TotalCount 30 MaxActive 6 SpawnCount 2 WaitBeforeStarting 0 WaitBetweenSpawns 10 TotalCurrency 100 TFBot { Class Scout Skill Expert CharacterAttributes { "move speed bonus" 1.5 "increase jump height" 1.2 } } }</pre>
--	---

Common Semantic Errors:

- Absolutely make sure the console does not report any keyvalue errors when you load your pop file. If it does, you must address them first, or else syntax errors may cause some of the strange behavior mentioned below which will make your debugging even more painful.
- If there is a checkerboard icon on the wave HUD, check your console. If it says “**Missing Vgui material vgui/./hud/leaderboard_class_iconname**” then you either misspelled your class icon name or the icon is not in your game files (it should be placed in *tf/materials/hud* or *tf/download/materials/hud*).
- If the wave hangs up (stops spawning robots, only support bots are spawning, etc) then these are the possible causes to investigate:

- o Check for every WaveSpawn and Mission you specify the Where property (the name of the spawn point the bots should use). If you do not specify the spawn point name, the server will not spawn those robots anywhere.
- o Check that your SpawnCount is not higher than your MaxActive. If it is, then the wavespawn will not spawn anything since when it tries to spawn the SpawnCount number of bots, it exceeds the wavespawn’s MaxActive so it halts.
- o The server allocates 22 player slots for bots (it’s like a global MaxActive across all wavespawns). Similar to the above bug, if there are too many bots out at once, and a wavespawn needs to spawn more bots but it would break the 22 bot limit (even if it doesn’t break its own MaxActive limit), it won’t spawn any bots in.

Wavespawns with large SpawnCount values (typically large squads) are prone to getting trapped by this bug. The most common cause of this is that the infinite support occupies too many bot slots, so you may need to lower its MaxActive or SpawnCount, or raise its WaitBetweenSpawns (or do a combination of that).

- o Make sure you do not have any wavespawns that have a WaitForAllDead/Spawned on a Support 1 wavespawn. If you do, the wave will hang up because that child wavespawn will never begin, since Support 1 wavespawns never are dead and never finish spawning.
- If a wave suddenly finishes despite the wave HUD and wave bar showing many bot icons, you have a circular reference of wavespawns that are waiting on each other. An example of this is wavespawn A waits for wavespawn B to finish, wavespawn B waits for wavespawn C to finish, and wavespawn C waits for wavespawn A. Since all 3 are waiting for each other and none of them can ever run, the server ignores all 3 wavespawns, which may cause the wave to end early.
- You may load a pop file and see that it features 38 giant pyros, even though your pop file has 3 giant pyros and 35 small pyros. This is because the two pyro templates share the same icon, so the game adds 3 + 35. The special effects on the wave HUD, like the red background and crit glow, are shown based on the icon’s bitflags. Since both pyros share the same icon, the giant pyros assign the red background flag to the icon, which makes all 38 pyros appear giant on the HUD.

Conclusion:

Pop file writing is not a difficult task, but like all things in life it takes practice to become comfortable at it. The challenge in designing MvM missions is not so much dealing with the syntax of pop files, but trying to create balanced, fun, and appropriately long waves.

Playing missions of pre-existing MvM missions (be it Valve or community) can give you inspiration and ideas on how to make a good MvM mission. Keep in mind that every mission has flaws (including Valve missions), so the challenge is to also detect the sore spots (bad design decisions) in a mission and avoid making those errors in your own mission.

For the syntax, if you want more information on what you can do with pop files, look at the in-game Valve pop files (found inside `tf_scripts_dir.vpk`) or pop files made by other community members. There isn't a whole lot more to the syntax that isn't covered here; you will find that you will only use 60-70% of all the features available in pop files in your mission.

The best way to learn pop files is by trial and error. This guide says a lot of things, but the only way to really learn is to do it yourself. Take the example pop file you made and change some things. Try making a large squad. Try making your own robot with special attributes. Try fiddling with the numbers (timing, money dropped, etc). The best way to learn is to try something and see how it changes what happens in the game. Do that enough times, and eventually all the puzzle pieces will come together to help you make your own mission. This guide is only good as a quick reference for something but not so much a tutorial.

If you have any questions about wave design, pop file syntax, debugging your mission or need testing for your mission, feel free to ask in [the steam group](#) forums or hop in the group chat.

If you want the syntax highlighter used in the screenshots, check our GitHub repository [here](#). You can tweak the colors and add keywords by editing the XML file by hand or using the given program. There is no support or warranty given to either the XML file or the program, so what you see is what you get!

If there are any mistakes, typos, grammar/punctuation issues, broken links, or the like, let us know in the group chat and we'll correct them. Thanks!

Good luck!

- **Hydrogen**
Owner of Potato's MvM Servers