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BEng. (Hons) in Software Engineering

MODULE: 6SENG003C.1 Reasoning about Programs

Coursework Report

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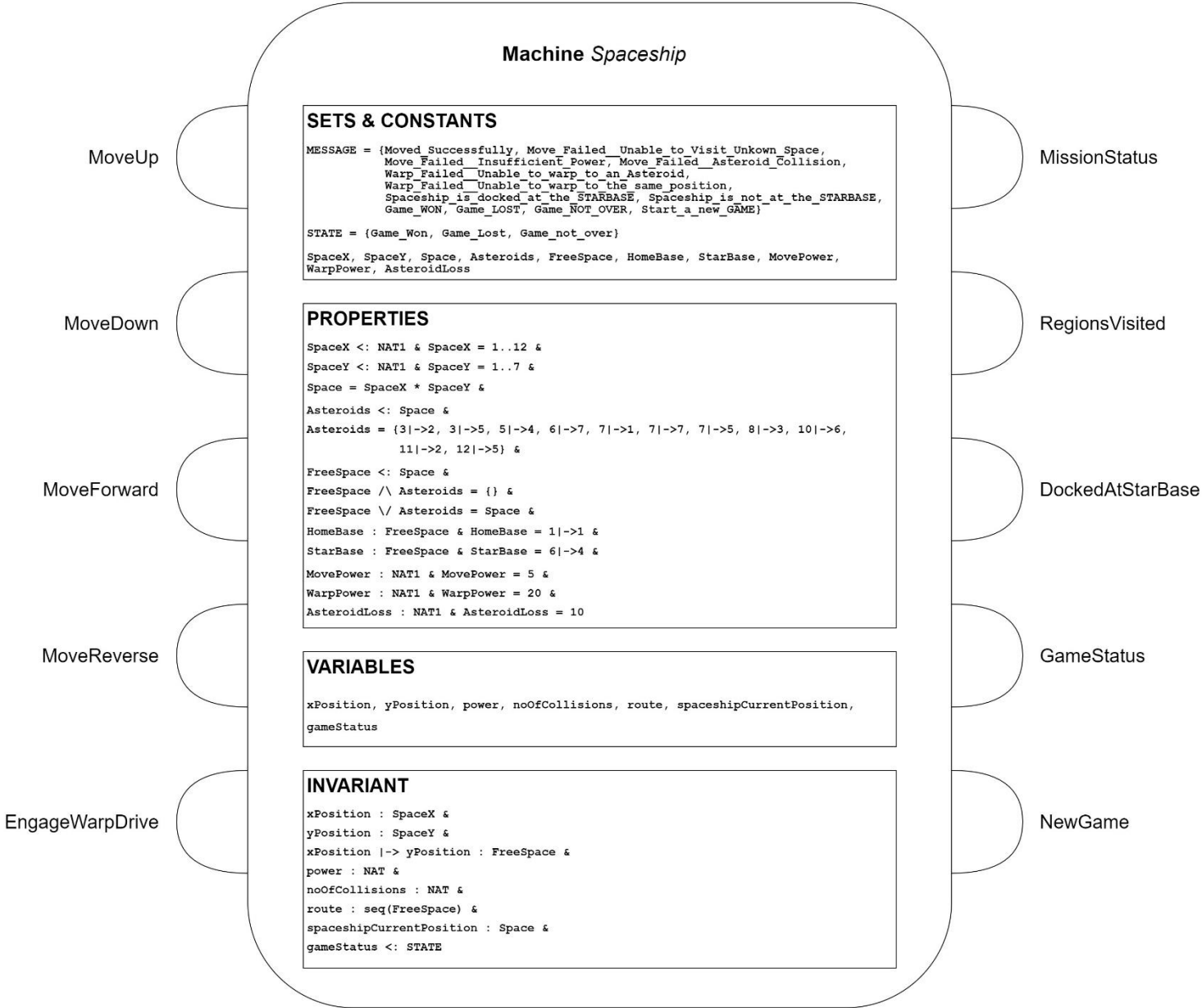
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1 Structure Diagram



2 Justification & the Explanation

The project is about developing a B specification of a simplified version of the Spaceship & Asteroids arcade game using B tools. Above diagram shows the relevant Structure diagram for the developed B specification. All the assigned and used SETS, CONSTANTS, PROPERTIES, VARIABLES & INVARIANTS are briefly explained down below for further understanding.

SETS

```
MESSAGE = {Moved_Successfully, Move_Failed_Unable_to_Visit_Unkown_Space,
Move_Failed_Insufficient_Power, Move_Failed_Asteroid_Collision,
Warp_Failed_Unable_to_warp_to_an_Asteroid,
Warp_Failed_Unable_to_warp_to_the_same_position,
Spaceship_is_docked_at_the_STARBASE, Spaceship_is_not_at_the_STARBASE,
Game_WON, Game_LOST, Game_NOT_OVER, Start_a_new_GAME};
```

```
STATE = {Game_Won, Game_Lost, Game_not_over}
```

Two main sets were initialized for the development of the project.

- MESSAGE set includes all the error, success and warning messages which were used throughout the game process to deliver the relevant message according the executed operation.
- Game consists of 3 main states (Win, Lose, In Progress) and STATE set was used for showing the current state of the game with every move of the spaceship.

CONSTANTS & PROPERTIES

```
SpaceX, SpaceY, Space, Asteroids, FreeSpace, HomeBase, StarBase, MovePower, WarpPower,
AsteroidLoss
```

```
SpaceX <: NAT1 & SpaceX = 1..12 &
SpaceY <: NAT1 & SpaceY = 1..7 &
Space = SpaceX * SpaceY &
Asteroids <: Space &
Asteroids = {3|->2, 3|->5, 5|->4, 6|->7, 7|->1, 7|->7, 7|->5, 8|->3, 10|->6, 11|->2, 12|->5} &
FreeSpace <: Space &
FreeSpace /\ Asteroids = {} &
FreeSpace \/ Asteroids = Space &
HomeBase : FreeSpace & HomeBase = 1|->1 &
StarBase : FreeSpace & StarBase = 6|->4 &
MovePower : NAT1 & MovePower = 5 &
WarpPower : NAT1 & WarpPower = 20 &
AsteroidLoss : NAT1 & AsteroidLoss = 10
```

Few constants were used in the implementation and the use of the relevant constants are justified as shown below.

- SpaceX – Used for showing the X axis of the defined space which includes values from 1 to 12.

- `SpaceY` – Used for showing the Y axis of the defined space which includes values from 1 to 7.
- `Space` – Refers to the whole area where the Spaceship has the ability to travel which is the product of `SpaceX` & `SpaceY`.
- `Asteroids` – Space includes few Asteroids distributed throughout the Space, hence Asteroids becomes a subset of Space and 11 Asteroids are placed in random locations through the space and they were defined using X-Y coordinate relationship.
- `FreeSpace` – Refers to the free space where the Spaceship can travel without asteroids hence it becomes a subset of the Space too. Asteroids occupies volume from the Space, therefore Asteroids and `FreeSpace` are mutually exclusive and union of both Asteroids and `FreeSpace` makes the Space.
- `HomeBase` – Refers to the starting position of the Spaceship. (1,1)
- `StarBase` – Refers to the game winning position. (6,4)
- `MovePower` – Power consumed by the spaceship for a normal movement operation.
- `WarpPower` – Power consumed by the spaceship for a warp jump.
- `AsteroidLoss` – Power lost due to collision with an asteroid.

VARIABLES & INVARIANTS

`xPosition, yPosition, power, noOfCollisions, route, spaceshipCurrentPosition, gameStatus`

```
xPosition : SpaceX &
yPosition : SpaceY &
xPosition |-> yPosition : FreeSpace &
power : NAT &
noOfCollisions : NAT &
route : seq(FreeSpace) &
spaceshipCurrentPosition : Space &
gameStatus <: STATE
```

Few variables were initialized to store the values of constantly changing parameters.

- `xPosition, yPosition` – `xPosition` refers to the x coordinate of the Spaceship's position hence it becomes an element of the `SpaceX`. `yPosition` refers to the y coordinate of the Spaceship's position hence it becomes an element of the `SpaceY`. `xPosition` and `yPosition` pair can only change their values within the `FreeSpace` hence the pair can be identified as an element of the `FreeSpace`.
- `power` – Used to store the changing power of the Spaceship, power value changes with every normal movement, warp jump and asteroid collision. This variable value can be used when determining whether the Game was lost or not.

- `noOfCollisions` – Refers to the counts of caused asteroid collisions throughout the game.
- `route` – Used to store the Spaceship's path from start to the end of the game, route should include multiple elements and duplicate values should be permitted hence route was defined as a sequence limited to the FreeSpace.
- `spaceshipCurrentPosition` – Refers to the current position of the Spaceship.
- `gameStatus` – Refers to the state property which describes the status of the game. (Win, Lose, In Progress)

INITIALISATION

```
power := 0 ||
noOfCollisions := 0 ||
xPosition := 1 ||
yPosition := 1 ||
route := [HomeBase] ||
spaceshipCurrentPosition := HomeBase ||
gameStatus := {}
```

- As per the specification Spaceship has no power, no collisions and should be located on the homebase at the start of the game hence variables were initialised considering those requirements.

3 Screenshots of the ProB window

1. Initialising the Game



2. Start of the Game

The screenshot shows the initial state of the game. The 'State Properties' panel on the left lists variables like `gameStatus`, `noOfCollisions`, `power`, `route`, `spaceshipCurrentPosition`, `xPosition`, `yPosition`, `SpaceX`, `SpaceY`, `Space`, `Asteroids`, `FreeSpace`, `HomeBase`, `StarBase`, `MovePower`, `WarpPower`, and `AsteroidLoss`. The 'Enabled operations' panel in the center shows a sequence of actions starting with `MoveUp-->Moved_Successfully` and `MoveDown-->Move_Failed_Unable_to_Visit_Unknown_Space`. The 'History' panel on the right shows the `NewGame(100)` operation.

3. Successful Normal Movement

The screenshot shows the game state after several successful movements. The 'State Properties' panel shows `power` at 90 and `spaceshipCurrentPosition` at (3, 1). The 'Enabled operations' panel shows a sequence of `EngageWarpDrive` operations, some of which are marked as `Warp_Failed_Unable_to_warp_to_an_Asteroid`. The 'History' panel shows the `NewGame(100)` operation.

4. Failed movement due to unknown space and asteroid collision

The screenshot shows the game state after a failed movement. The 'State Properties' panel shows `power` at 80 and `spaceshipCurrentPosition` at (3, 1). The 'Enabled operations' panel shows a sequence of `EngageWarpDrive` operations, some of which are marked as `Warp_Failed_Unable_to_warp_to_an_Asteroid`. The 'History' panel shows the `NewGame(100)` operation.

5. Successful warp jump

The screenshot shows the game state after a successful warp jump. The 'State Properties' panel shows `power` at 60 and `spaceshipCurrentPosition` at (5, 6). The 'Enabled operations' panel shows a sequence of `EngageWarpDrive` operations, some of which are marked as `Warp_Failed_Unable_to_warp_to_an_Asteroid`. The 'History' panel shows the `NewGame(100)` operation.

6. Failed warp jump due to same position, asteroid collision and unknown space errors

The screenshot displays the Godot 4.0.3 IDE interface with three panels open at the bottom:

- State Properties (22):** Shows the configuration for a game object. Key properties include:
 - `gameStatus = {Game_not_over}`
 - `noOfCollisions = 1`
 - `power = 40`
 - `route(1) = {1}->{1}`
 - `route(2) = {2}->{1}`
 - `route(3) = {3}->{1}`
 - `route(4) = {5}->{6}`
 - `route(5) = {10}->{7}`
 - `spaceshipCurrentPosition = {10}->{7}`
 - `xPosition = 10`
 - `yPosition = 7`
 - `SpaceX = {1,2,3,4,5,6,7,8,9,10,11,12}`
 - `SpaceY = {1,2,3,4,5,6,7}`
 - `Space = {{1}->{1}, {1}->{2}, {1}->{3}, {1}->{4}, {1}->{5}, {1}->{6}, {1}->{7}, {2}->{1}, {2}->{2}, {2}->{3}, {2}->{4}, {2}->{5}, {3}->{2}, {3}->{3}, {3}->{4}, {3}->{5}, {4}->{3}, {4}->{4}, {4}->{5}, {4}->{6}, {5}->{4}, {5}->{5}, {5}->{6}, {5}->{7}, {6}->{5}, {6}->{6}, {6}->{7}, {7}->{6}, {7}->{7}, {7}->{8}, {8}->{7}, {8}->{8}, {8}->{9}, {9}->{8}, {9}->{9}, {10}->{9}, {10}->{10}, {10}->{11}, {10}->{12}, {11}->{10}, {11}->{11}, {11}->{12}, {12}->{11}, {12}->{12}}`
 - `FreeSpace = {{1}->{1}, {1}->{2}, {1}->{3}, {1}->{4}, {1}->{5}, {1}->{6}, {1}->{7}, {2}->{1}, {2}->{2}, {2}->{3}, {2}->{4}, {2}->{5}, {3}->{2}, {3}->{3}, {3}->{4}, {3}->{5}, {4}->{3}, {4}->{4}, {4}->{5}, {4}->{6}, {5}->{4}, {5}->{5}, {5}->{6}, {5}->{7}, {6}->{5}, {6}->{6}, {6}->{7}, {7}->{6}, {7}->{7}, {7}->{8}, {8}->{7}, {8}->{8}, {8}->{9}, {9}->{8}, {9}->{9}, {10}->{9}, {10}->{10}, {10}->{11}, {10}->{12}, {11}->{10}, {11}->{11}, {11}->{12}, {12}->{11}, {12}->{12}}`
 - `HomeBase = {{1}->{1}}`
 - `StarBase = {{8}->{4}}`
 - `MovePower = 5`
 - `WarpPower = 20`
 - `AsteroidLoss = 10`
- Enabled operations (109):** Lists 109 operations, including:
 - `EngageWarpDrive(10,6)-->Warp_Failed_Unable_to_warp_to_an_Asteroid`
 - `EngageWarpDrive(11,6)-->Moved_Successfully`
 - `EngageWarpDrive(12,6)-->Moved_Successfully`
 - `EngageWarpDrive(1,7)-->Moved_Successfully`
 - `EngageWarpDrive(2,7)-->Moved_Successfully`
 - `EngageWarpDrive(3,7)-->Moved_Successfully`
 - `EngageWarpDrive(4,7)-->Moved_Successfully`
 - `EngageWarpDrive(5,7)-->Moved_Successfully`
 - `EngageWarpDrive(6,7)-->Warp_Failed_Unable_to_warp_to_an_Asteroid`
 - `EngageWarpDrive(7,7)-->Warp_Failed_Unable_to_warp_to_an_Asteroid`
 - `EngageWarpDrive(8,7)-->Moved_Successfully`
 - `EngageWarpDrive(9,7)-->Moved_Successfully`
 - `EngageWarpDrive(10,7)-->Warp_Failed_Unable_to_warp_to_the_same_position`
 - `EngageWarpDrive(11,7)-->Moved_Successfully`
 - `EngageWarpDrive(12,7)-->Moved_Successfully`
 - `EngageWarpDrive(13,11)-->Move_Failed_Unable_to_Visit_Unknown_Space`
 - `EngageWarpDrive(14,11)-->Move_Failed_Unable_to_Visit_Unknown_Space`
 - `EngageWarpDrive(15,11)-->Move_Failed_Unable_to_Visit_Unknown_Space`
 - `EngageWarpDrive(16,11)-->Move_Failed_Unable_to_Visit_Unknown_Space`
 - `EngageWarpDrive(17,11)-->Move_Failed_Unable_to_Visit_Unknown_Space`
 - `EngageWarpDrive(18,11)-->Move_Failed_Unable_to_Visit_Unknown_Space`
 - `EngageWarpDrive(19,11)-->Move_Failed_Unable_to_Visit_Unknown_Space`
 - `EngageWarpDrive(20,11)-->Move_Failed_Unable_to_Visit_Unknown_Space`
- History (12):** Shows a list of 12 operations performed:
 - `EngageWarpDrive(20,11)-->Move_Failed_Unable_to_Visit_Unknown_Space`
 - `EngageWarpDrive(10,7)-->Warp_Failed_Unable_to_warp_to_the_same_position`
 - `EngageWarpDrive(6,7)-->Warp_Failed_Unable_to_warp_to_an_Asteroid`
 - `EngageWarpDrive(10,7)-->Moved_Successfully`
 - `EngageWarpDrive(5,6)-->Moved_Successfully`
 - `MoveUp-->Move_Failed_Asteroid_Collision`
 - `MoveDown-->Move_Failed_Unable_to_Visit_Unknown_Space`
 - `MoveForward-->Moved_Successfully`
 - `MoveForward-->Moved_Successfully`
 - `NewGame(100)-->Start_a_new_GAME`
 - `INITIALISATION(gameStatus={},noOfCollisions=0,power=0,route={{1}->{1}}),spaceshipCurrentPosition={10}->{7},SpaceX={1,2,3,4,5,6,7,8,9,10,11,12},SpaceY={1,2,3,4,5,6,7},Space=`

7. Failed warp jump due to insufficient power

8. Game Lost

The screenshot displays the Visual Studio Code interface with three panels. The left panel, titled 'State Properties (27)', lists various game state variables. The middle panel, titled 'Enabled operations (5)', shows a sequence of actions. The right panel, titled 'History (19)', shows a log of game events.

State Properties (27):

- invariant_ok
- gameStatus = {Game_Lost}
- noOfCollisions = 1
- power = 0
- route(1) = {1}->1}
- route(2) = {2}->1}
- route(3) = {3}->1}
- route(4) = {5}->6}
- route(5) = {10}->7}
- route(6) = {2}->1}
- route(7) = {3}->1}
- route(8) = {4}->1}
- route(9) = {5}->1}
- route(10) = {5}->2}
- spaceship_CurrentPosition = {5}->2}
- xPosition = 5
- yPosition = 2
- SpaceX = {1,2,3,4,5,6,7,8,9,10,11,12}
- SpaceY = {1,2,3,4,5,6,7}
- Space = {(11)->1}, {(1)->2}, {(1)->3}, {(1)->4}, {(1)->5}, {(1)->6}, {(1)->7}, {(2)->1}, {(2)->2}, {(2)->3}, {(2)->4}, {(2)->5}, {(3)->2}, {(3)->5}, {(5)->4}, {(6)->7}, {(7)->1}, {(7)->5}, {(7)->7}, {(8)->3}, {(10)->6}, {(11)->2}, {(12)->5}
- FreeSpace = {(11)->1}, {(1)->2}, {(1)->3}, {(1)->4}, {(1)->5}, {(1)->6}, {(1)->7}, {(2)->1}, {(2)->2}, {(2)->3}, {(2)->4}, {(2)->5}
- HomeBase = {1}->1}
- StarBase = {6}->4}
- MovePower = 5
- WarpPower = 20
- AsteroidLoss = 10

Enabled operations (5):

- NewGame(100)-->Start_a_new_GAME
- MissionStatus-->{5}->2,0,1
- RegionsVisited-->{(11)->1}, {(2)->2}, {(3)->2}, {(3)->1}, {(4)->5}, {(5)->6}, {(5)->10}, {(6)->2}, {(6)->2}->1
- DockedAtStarBase-->Spaceship_is_not_at_the_STARBASE
- GameStatus-->Game_LOST

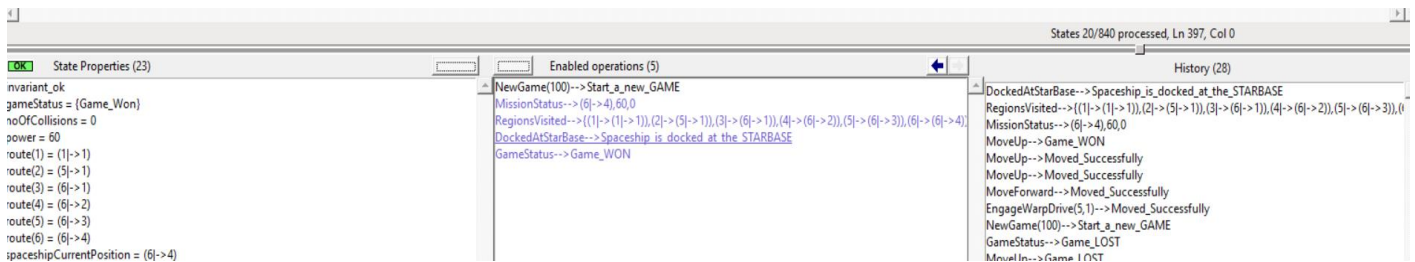
History (19):

- GameStatus-->Game_LOST
- MoveUp-->Game_LOST
- MoveForward-->Moved_Successfully
- MoveForward-->Moved_Successfully
- EngageWarpDrive(1,1)-->Move_Failed_Insufficient_Power
- MoveForward-->Moved_Successfully
- EngageWarpDrive(2,1)-->Moved_Successfully
- EngageWarpDrive(20,1)-->Move_Failed_Unable_to_Visit_Unknown_Space
- EngageWarpDrive(10,7)-->Warp_Failed_Unable_to_warp_to_the_same_position
- EngageWarpDrive(6,7)-->Warp_Failed_Unable_to_warp_to_an_Asteroid
- EngageWarpDrive(10,7)-->Moved_Successfully
- EngageWarpDrive(5,6)-->Moved_Successfully
- MoveUp-->Move_Failed_Asteroid_Collision
- MoveDown-->Move_Failed_Unable_to_Visit_Unknown_Space
- MoveForward-->Moved_Successfully
- MoveForward-->Moved_Successfully
- NewGame(100)-->Start_a_new_GAME
- INITIALISATION(gameStatus={noOfCollisions=0,power=0,route={(11)->1}},spac
- SETUP_CONSTANTS(SpaceX={1,2,3,4,5,6,7,8,9,10,11,12},SpaceY={1,2,3,4,5,6,7},Space={

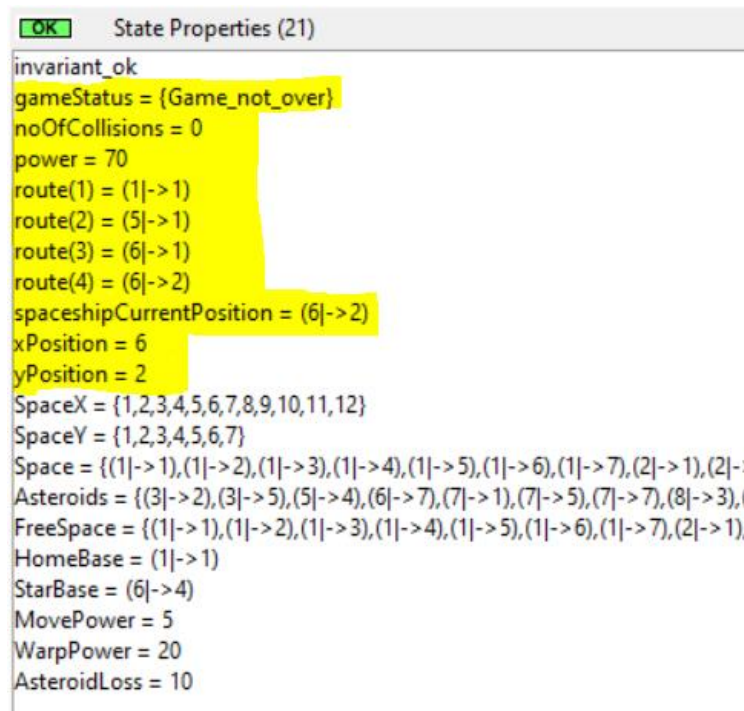
9. Game Won

The screenshot displays the Visual Studio Code interface with three panels: 'State Properties (23)', 'Enabled operations (5)', and 'History (25)'. The 'State Properties' panel lists various game state variables, including 'gameStatus' (Game_Won), 'noOfCollisions' (0), 'power' (60), 'route' (an array of 6 elements), 'spaceshipCurrentPosition' (6, 4), 'SpaceX' (an array of 12 elements), 'SpaceY' (an array of 6 elements), 'Space' (an array of 11 elements), 'Asteroids' (an array of 5 elements), 'FreeSpace' (an array of 6 elements), 'HomeBase' (1), 'StarBase' (6), 'MovePower' (5), 'WarpPower' (20), and 'AsteroidLoss' (10). The 'Enabled operations' panel lists actions such as 'NewGame(100)', 'MissionStatus', 'RegionsVisited', 'DockedAtStarBase', and 'GameStatus'. The 'History' panel shows a sequence of events from 'MoveUp--> Game_WON' to 'INITIALISATION()'. The 'INITIALISATION()' operation sets initial values for 'noOfCollisions', 'power', 'route', 'spaceshipCurrentPosition', 'SpaceX', 'SpaceY', 'Space', 'Asteroids', 'FreeSpace', 'HomeBase', 'StarBase', 'MovePower', 'WarpPower', and 'AsteroidLoss'.

10. Status of the mission, Spaceship visited regions, Spaceship docked at starbase or not

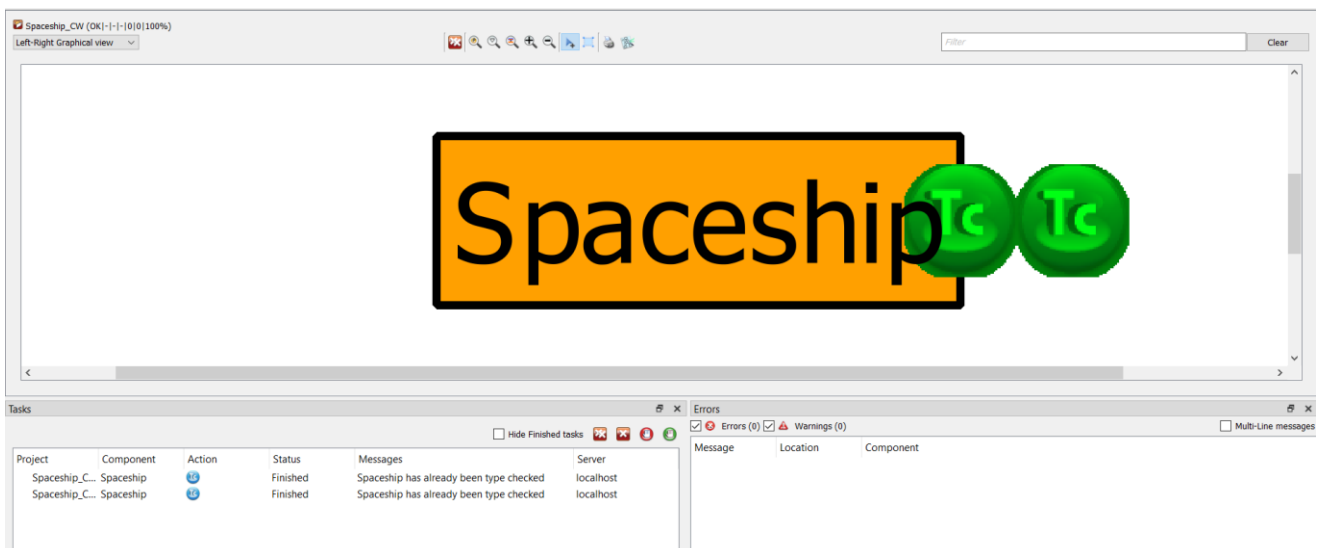


11. State Properties



Highlighted state values change with the movement of the spaceship.

4 Screenshot of the Atelier B Type Check



5 Spaceship Graphical Visualisation

