cFS Basecamp
Hello Table Coding Lessons

Version 1.9

October 2023

Introduction

- **Objectives**
  - Provide documentation for the Hello World coding tutorials
  - Basecamp
- **Intended Audience**
  - Software developers that want to develop cFS applications
- **Prerequisites**
  - Basic understanding of flight software context, the cFS architecture, and the cFS Application Developer's Guide
  - Working knowledge of the C programming language

Table Introduction

- Tables are a collection of related parameters
- Use tables to define parameters that could potential change, avoid #defines
- If only a couple of parameters then a command may suffice
- If okay to restart the app then init file okay

- cFS vs Basecamp Tables
- Same JSON parser as the init file processing
- Table validation


Hello Table Functionality and Operations

Hello Table Functionality

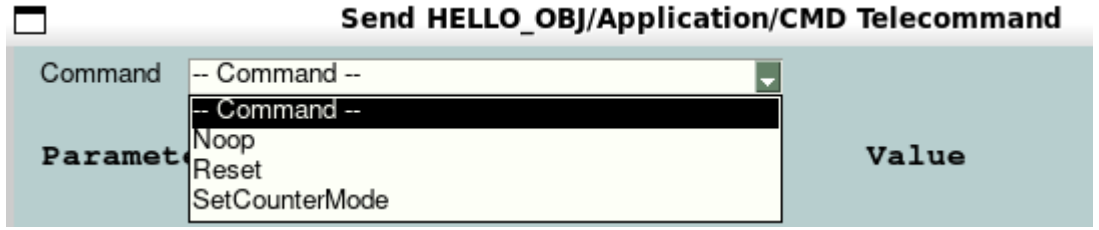
- **Functional modifications to Hello Object**
  - The EDS-defined Counter Mode type is in the status telemetry message (retained from coding lesson)
  - The EXOBJ_Execute() event message is defined as a DEBUG event and an event filter allows the first 8 events to be published (retained from coding lesson)
  - The App reset command resets the event filter. EXOBJ does not have any reset behavior.
  - The counter limits are defined in a new parameter

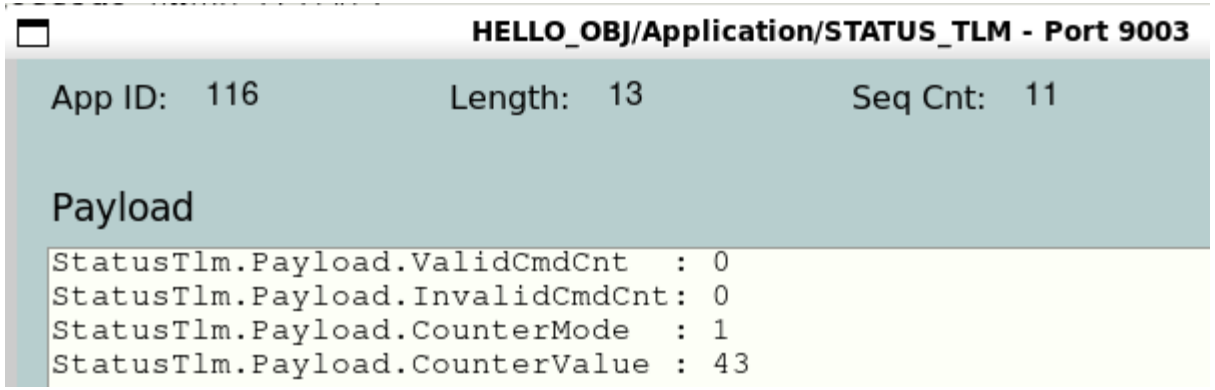
- **Additional functionality**
  - The increment and decrement modes have separate low and high limits
  - The Set Mode command sends the limits in an information event message
  - A Table Load command reads/parses a JSON table file and loads the new parameters values into variables
  - A table load callback acceptance function, owned by EXOBJ, is called when a new table is loaded. The default functionality is to accept the table and send an event message. A coding lesson adds functionality to the acceptance function.
  - A Table Dump command creates a JSON table file using the parameters values from variables

Hello Object Operations

Commands

- Retain Hello World's Noop and Reset commands
- New Set Counter Mode command





Telemetry

- Retain Hello World command valid/invalid counters
- New Counter Mode data point
  - A code exercise changes the EDS definition so this will be a descriptive string
- New Counter Value data point
  - The counter updated at 1Hz and the status telemetry is sent every 4 seconds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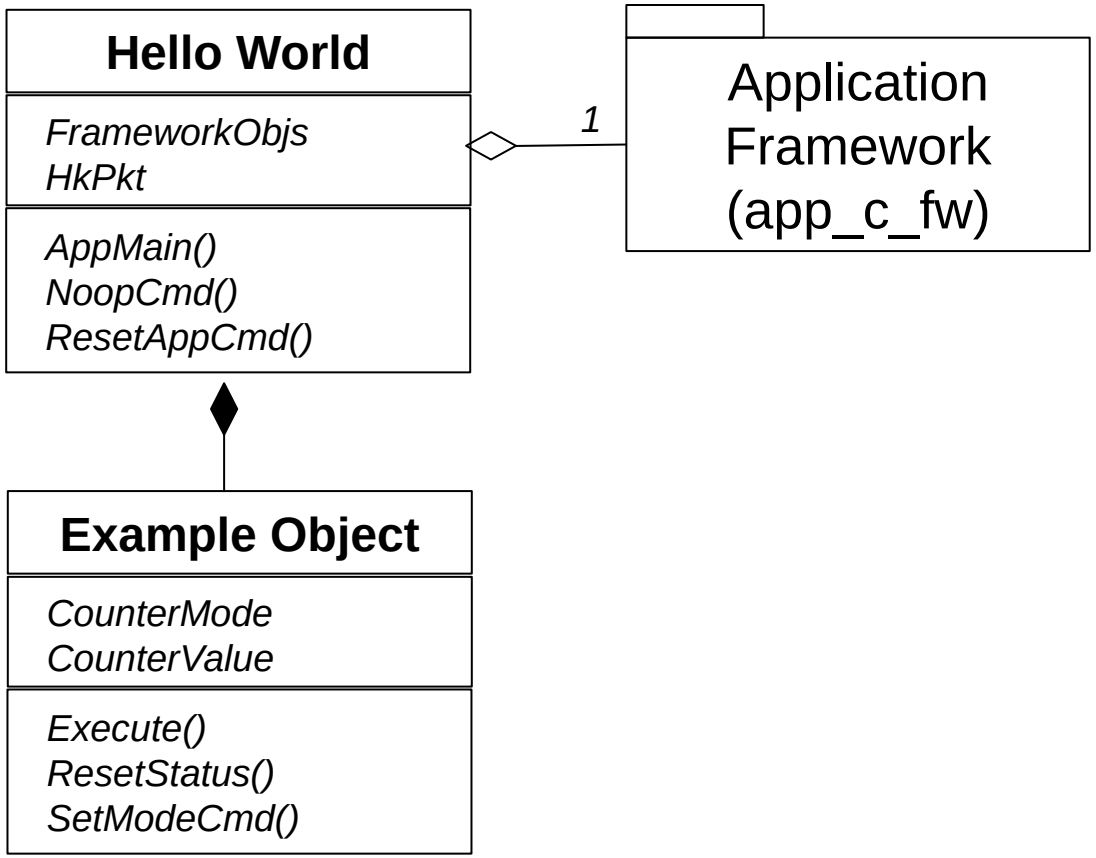
Hello Table Design

Hello Table Design

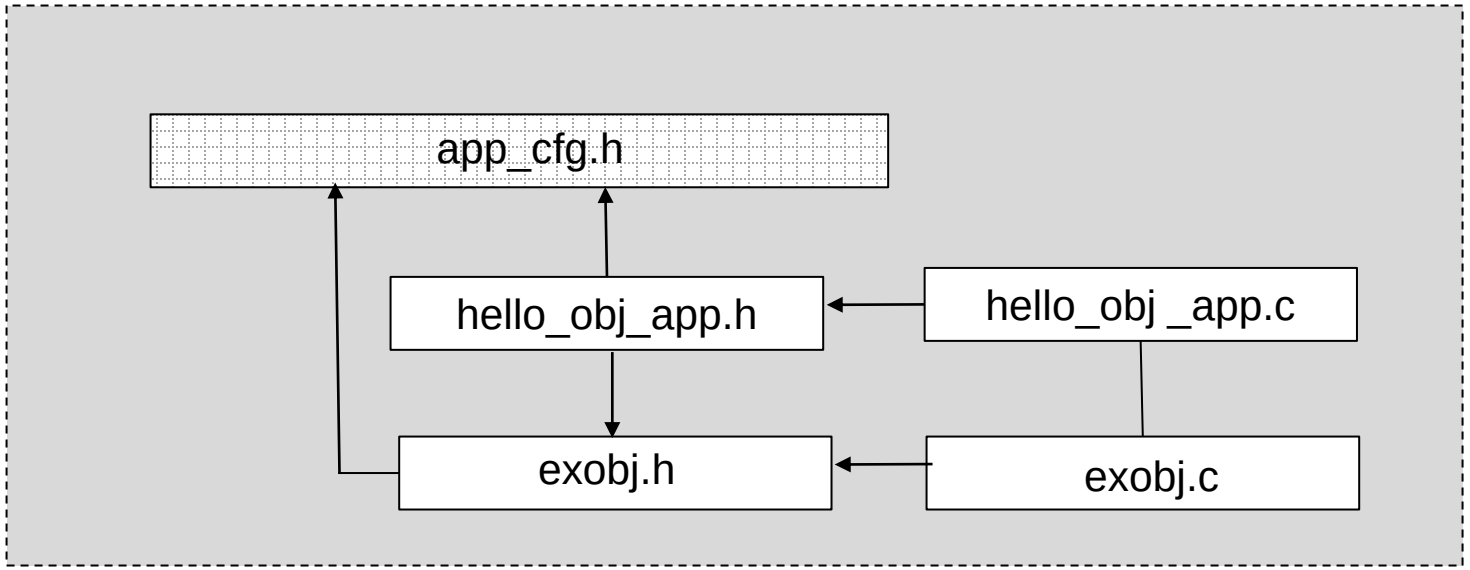
- **App Design (Note coupling)**
  - Example Object owns and constructs the table
  - Default table name defined in init table which impacts app_cfg.h
  - TBLMGR owned by app and constructed prior ro objects that register a table
  - EDS table name enumeration convention. Can’t parameterize enum in app_c_fw EDS
  - App_c_fw command codes and predefined table load/dump
  - Status telemetry conventions
  - Example Object owns and constructs the table

Hello Object Design



Hello Object Source Files

App Source Files



- app_cfg.h has additional ‘standard’ includes that are not shown, see App Dev Guide for details
- Hello_obj includes exobj.h so it can declare an instance of EXOBJ in its class data

```
typedef struct
{

    /*
    ** App Framework
    */

    INITBL_Class_t  IniTbl;
    CMDMGR_Class_t  CmdMgr;

    /*
    ** Telemetry Packets
    */

    HELLO_OBJ_StatusTlm_t  StatusTlm;

    /*
    ** HELLO_OBJ State & Contained Objects
    */

    uint32            PerfId;
    CFE_SB_PipeId_t   CmdPipe;
    CFE_SB_MsgId_t    CmdMid;
    CFE_SB_MsgId_t    ExecuteMid;
    CFE_SB_MsgId_t    SendStatusMid;

    EXOBJ_Class_t  ExObj;

} HELLO_OBJ_Class_t;
```

Application Run Loop Messaging Example

Suspend execution until a message arrives on app's pipe

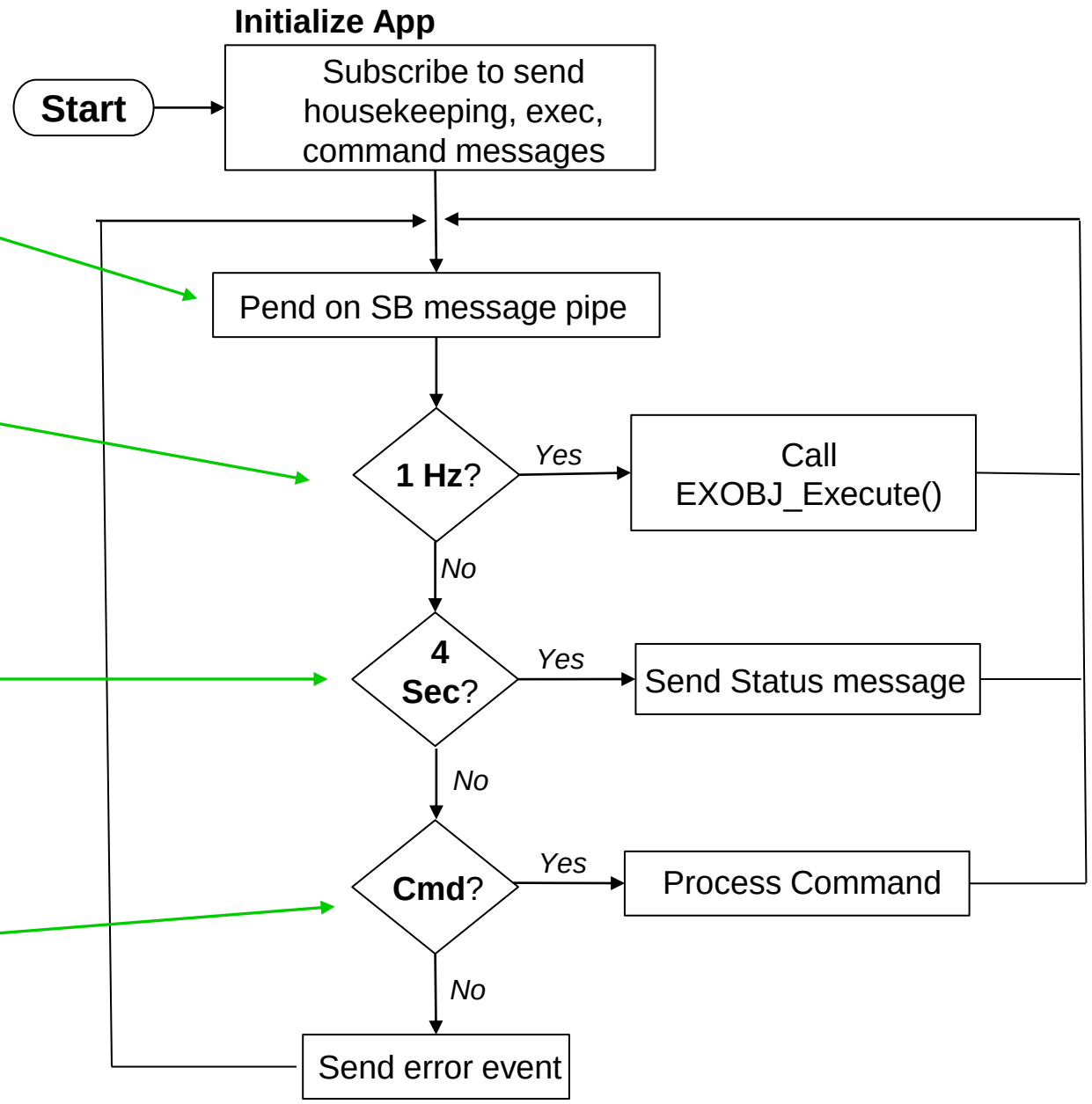
Periodic *1Hz* message from SCH app

Periodic *4 second* message from SCH app

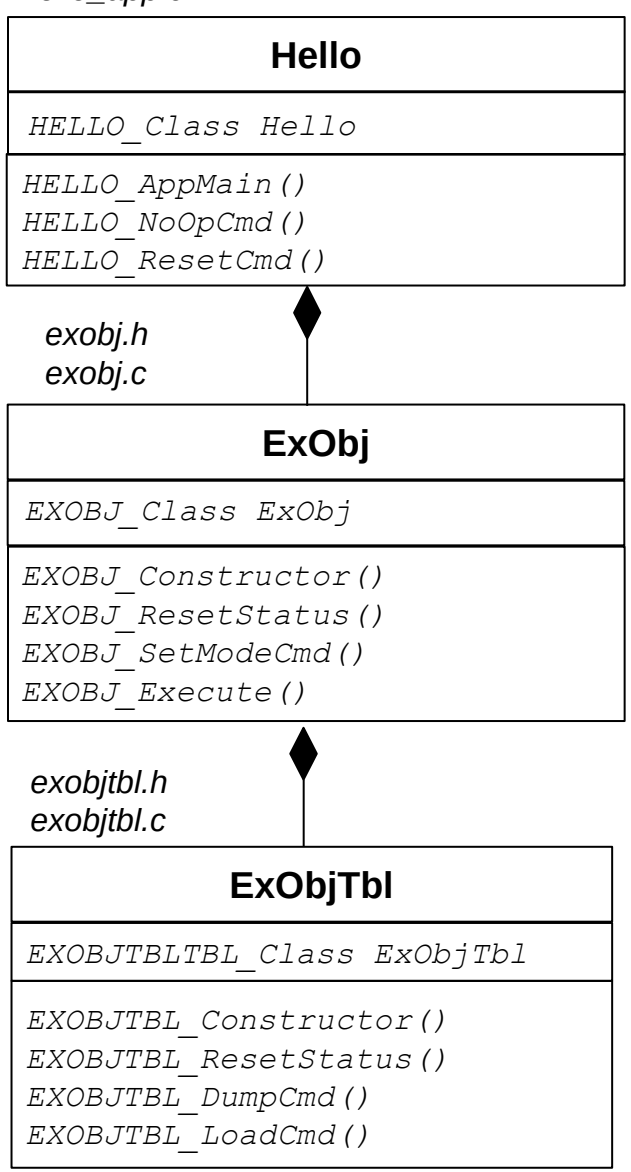
- Send status telemetry message
- "Housekeeping cycle" convenient time to perform non-critical functions

Process commands

- Commands can originate from ground or other onboard apps



Lesson 1 Design Highlights



- **The App C Framework is an object-based design written in C**
- **Apps are constructed as an aggregation of objects**
  - Hello contains one Example Object (ExObj)
  - ExObj contains one Example Object Table (ExObjTbl)
  - The object hierarchy can be as wide or deep as needed
- **The key roles of the main app are to**
  - Read the app's JSON initialization configuration file
  - Initialize contained objects and register their commands
  - Manage the main control loop
- **Contained objects implement the 'business logic'**
  - ExObj increments a counter during each execution cycle
  - ExObj's Set Mode command supports increment and decrement
  - ExObjTbl defines the counter's lower and upper limits

hello_app.h

```
97 typedef struct
98 {
99
100    /*
101    ** App Framework
102    */
103
104    INITBL_Class_t    IniTbl;
105    CMDMGR_Class_t    CmdMgr;
106    TBLMGR_Class_t    TblMgr;
107
108    /*
109    ** Command Packets
110    */
111
112
113    /*
114    ** Telemetry Packets
115    */
116
117    HELLO_HkPkt_t  HkPkt;
118
119    /*
120    ** HELLO State & Contained Objects
121    */
122
123    CFE_SB_PipeId_t  CmdPipe;
124    CFE_SB_MsgId_t   CmdMid;
125    CFE_SB_MsgId_t   ExecuteMid;
126    CFE_SB_MsgId_t   SendHkMid;
127    uint32           PerfId;
128
129    EXOBJ_Class_t  ExObj;
130
131 } HELLO_Class_t;
```

- **Use a variation of the 'singleton" design pattern**
  - Object constructors passed reference to owner's storage
  - `void EXOBJ_Constructor(EXOBJ_Class_t* ExObjPtr, const INITBL_Class_t* IniTbl);`
  - Contained objects store reference a static variable so subsequent function (or method) calls don't require a pointer to be passed

exobj.h

```
81 typedef struct
82 {
83
84    /*
85    ** State Data
86    */
87
88    EXOBJ_CounterModeType_t  CounterMode;
89    uint16  CounterValue;
90
91    /*
92    ** Contained Objects
93    */
94
95    EXOBJTBL_Class_t  Tbl;
96
97 } EXOBJ_Class_t;
```

exobjtbl.h

```
73 typedef struct
74 {
75
76    /*
77    ** Table parameter data
78    */
79
80    EXOBJTBL_Data_t Data;
81
82    /*
83    ** Standard CJSON table data
84    */
85
86    const char*  AppName;
87    bool         Loaded;    /* Has
88    uint8        LastLoadStatus;
89    uint16       LastLoadCnt;
90
91    size_t       JsonObjCnt;
92    char         JsonBuf[EXOBJTBL_
93    size_t       JsonFileLen;
94
95 } EXOBJTBL_Class_t;
```

Add Event Messages to ExObj Execute()

Lesson 1 Design Highlights

```
├─cfsat_defs/
│  └─cpu1_hello_tbl.json
└─cfs-apps/
  └─hello/
    ├─eds/
    ├─fsw/src/
      └─exobj.c
```

- **Open *./cfs-apps/hello/fsw/src/exobj.c in a text editor***
- **Event message function call**
  - `CFE_EVE_SendEvent(Event ID, Event Type, Format String, Values)`
- **Add events as show below**
  1. Send event when increment mode reaches its high limit
  2. Send event when decrement mode reaches its low limit

```
128 void EXOBJ_Execute(void)
129 {
130
131    if (ExObj->CounterMode == EXOBJ_CounterModeType_INCREMENT)
132    {
133       if (ExObj->CounterValue < ExObj->Tbl.Data.HighLimit)
134       {
135          ExObj->CounterValue++;
136       }
137       else
138       {
139          ExObj->CounterValue = ExObj->Tbl.Data.LowLimit;
140       }
141    } /* End if increment */
142    else
143    {
144       if (ExObj->CounterValue > ExObj->Tbl.Data.LowLimit)
145       {
146          ExObj->CounterValue--;
147       }
148       else
149       {
150          ExObj->CounterValue = ExObj->Tbl.Data.HighLimit;
151       }
152    } /* End if decrement */
153
154
155    CFE_EVS_SendEvent (EXOBJ_EXECUTE_EID, CFE_EVS_EventType_DEBUG,
156                       "%s counter mode: Value %d",
157                       CounterModeStr(ExObj->CounterMode), ExObj->CounterValue);
158
159 } /* End EXOBJ_Execute() */
```

1

2

```
131    if (ExObj->CounterMode == EXOBJ_CounterModeType_INCREMENT)
132    {
133       if (ExObj->CounterValue < ExObj->Tbl.Data.HighLimit)
134       {
135          ExObj->CounterValue++;
136       }
137       else
138       {
139          ExObj->CounterValue = ExObj->Tbl.Data.LowLimit;
140          CFE_EVS_SendEvent (EXOBJ_EXECUTE_EID, CFE_EVS_EventType_INFORMATION,
141                             "%s counter mode: Value reached high limit %d, resetting to low limit %d",
142                             CounterModeStr(ExObj->CounterMode),
143                             ExObj->Tbl.Data.HighLimit,
144                             ExObj->Tbl.Data.LowLimit);
145       }
146    } /* End if increment */
147    else
148    {
149       if (ExObj->CounterValue > ExObj->Tbl.Data.LowLimit)
150       {
151          ExObj->CounterValue--;
152       }
153       else
154       {
155          ExObj->CounterValue = ExObj->Tbl.Data.HighLimit;
156          CFE_EVS_SendEvent (EXOBJ_EXECUTE_EID, CFE_EVS_EventType_INFORMATION,
157                             "%s counter mode: Value reached low limit %d, resetting to high limit %d",
158                             CounterModeStr(ExObj->CounterMode),
159                             ExObj->Tbl.Data.LowLimit,
160                             ExObj->Tbl.Data.HighLimit);
161       }
162    } /* End if decrement */
```

Change Default Counter Limits

- Open *./cfe-eds-framework/cfsat_defs/cpu1_hello_tbl.json in a text editor*
- Change low limit from 0 to 50
- Change high limit from 100 to 60

```
cfsat
├-cfe-eds-framework/
│  ├-cfsat_defs/
│  │  └-cpu1_hello_tbl.json
```

```
1 {
2    "app-name": "HELLO",
3    "tbl-name": "Limits",
4    "description": "Example table",
5    "low-limit":  0,
6    "high-limit": 100
7 }
```

1

```
1 {
2    "app-name": "HELLO",
3    "tbl-name": "Limits",
4    "description": "Example table",
5    "low-limit":  50,
6    "high-limit": 60
7 }
```

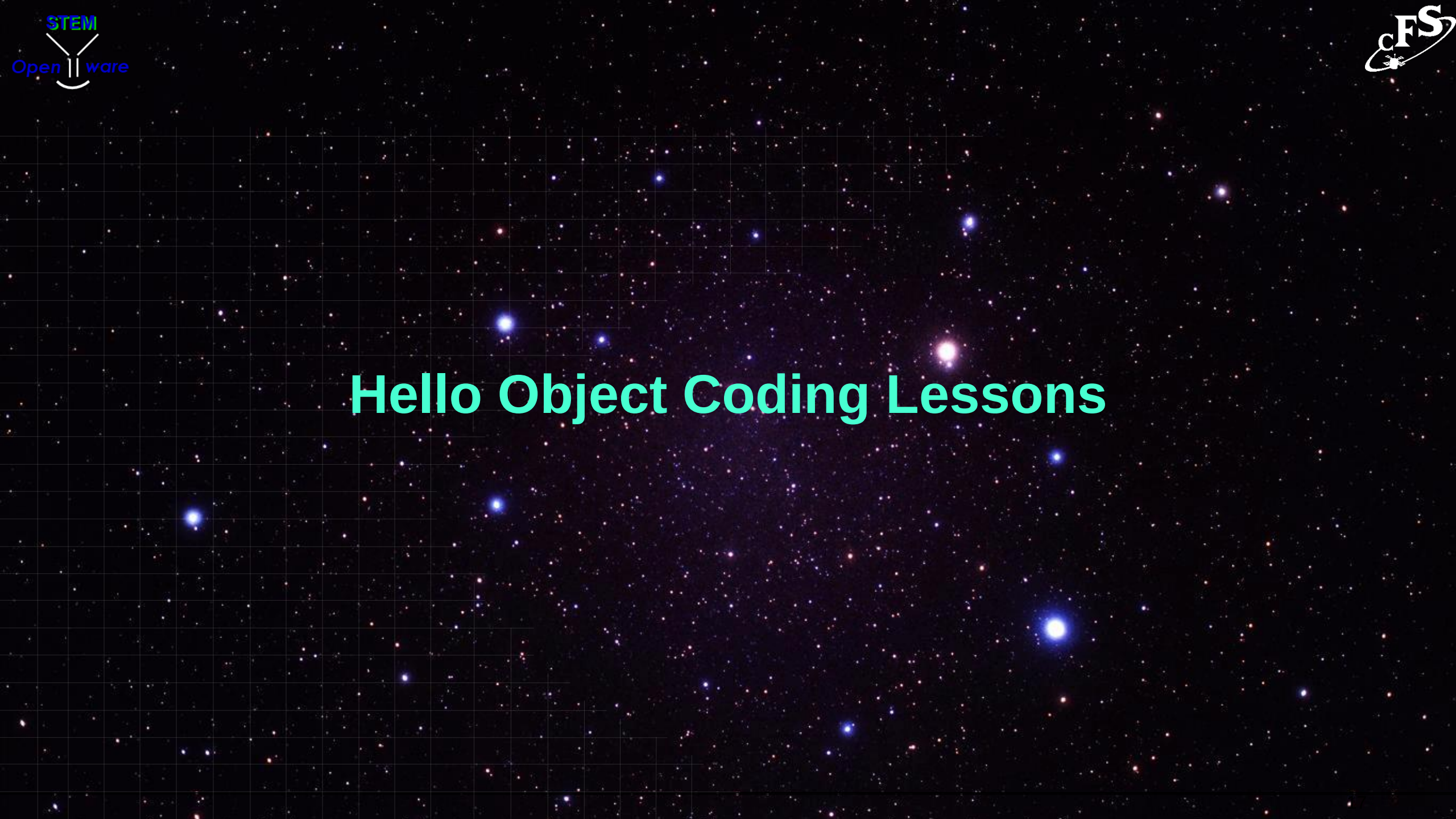
Build and cFS with Updated Example Object

```
cfsat
├─cfe-eds-framework/
└─build/exe/
        └─cpu1/
          └─cf/
```

1. **Change directory to *./cfe-eds-framework/***
   - `Make install`
2. **Change directory to *./cfe-eds-framework/build/exe/cpu1***
   - `./core-cpu1`
3. **From a different terminal change directory to ./cfsat/gnd-sys/app**
   - `. ./setvars.sh`
   - `Python3 cfsat.py`
   - `cFSAT: cFS Config -> Enable Telemetry`
4. **Try hello's Set Mode Command to verify your changes behave as expected**

Ground & Flight Events Clear

```
07:10:42 - cFSAT version 0.1.0 initialized with mission samplemission, target cpu1 on 02/06/2022
07:10:42 - cFSAT target host 127.0.0.1, command port 1234, telemetry port 1235
07:10:48 - TO_LAB EnableOutputCmd command sent
07:10:49 - CFE_EVS AddEventFilterCmd command sent
07:10:49 - CFE_EVS AddEventFilterCmd command sent
07:10:50 - FSW Event at 1001153: TO_LAB_APP, 2 - TO telemetry output enabled for IP 127.0.0.1
07:10:52 - FSW Event at 1001156: CFE_TIME, 2 - Start FLYWHEEL
07:10:54 - FSW Event at 1001158: CFE_TIME, 2 - Stop FLYWHEEL
07:11:25 - Created telemetry screen for HELLO/Application/HK_TLM
07:11:42 - FSW Event at 1001206: HELLO, 2 - INCREMENT counter mode: Value reached high limit 60, resetting to low limit 50
07:11:53 - FSW Event at 1001217: HELLO, 2 - INCREMENT counter mode: Value reached high limit 60, resetting to low limit 50
07:12:05 - FSW Event at 1001228: HELLO, 2 - INCREMENT counter mode: Value reached high limit 60, resetting to low limit 50
07:12:16 - FSW Event at 1001239: HELLO, 2 - INCREMENT counter mode: Value reached high limit 60, resetting to low limit 50
```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Hello Object Coding Lessons

Lesson 1 – Add EDS Enum Type to Status Telemetry (1 of 2)

Objectives

- Increase knowledge of EDS
- Show app_cfg.h EDS include

Design

- **TBD**

Lesson 1 – Add EDS Enum Type to Status Telemetry (2 of 2)

Verification

- Open telemetry page and see default mode
- Issue mode command to decrement

Lesson 2 – Move Limits to JSON Init File (1 of 2)

Objectives

- Reinforce Hello World JSON init
- App_cfg.h architectural role
- Object based encapsulation
- Ini file app level management and relationship to objects

Design

- **TBD**

Lesson 2 – Move Limits to JSON Init File (2 of 2)

Verification

- After app starts observe new range taking effect
- Change limits and restart app

Lesson 3 – Add Event Message Filter (1 of 2)

Objectives

- Introduce event types and event filters
- Use an object with a periocid function that is triggered by SCH message
- Deeper dive into app architecture, resources, roles and responsibilties

Design

- **TBD**

Lesson 3 – Add Event Message Filter (2 of 2)

Verification

- Observe the 8 execute event messages
- Reset filter by restting the app

Lesson 4 – Add Object Reset Functionality (1 of 2)

Objectives

- Show how objects can have functional requirements for the App's Reset command
- Show another usage of the Execute message as debug so when you enable it it can help but doesn't flood

Design

- **TBD**

- **Objectives**
- **Verify**
  - Reset app to see it go to the low limit
  - Change mode to decrement, wait and then reset to show it is reset to the high limit
  - Enable dubug messages and see the execute debug events
  - Reset app and show the filter is reset and applies to any event types

Lesson 4 – Add Object Reset Functionality (2 of 2)

Verification

- Reset app to observe it go to the low limit
- Change mode to decrement, wait and then reset to show it is reset to the high limit
- Enable dubug messages and see the execute debug events
- Reset app and show the filter is reset and applies to any event types