

Design Project Description
R2D2¹
Version 1

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Non DFEC Project Affiliate/Affiliated DF Department: *N/A.*

Customer/ Customer's Agency: *N/A.*

Project Description: *R2-D2 is a mascot for DFEC and its purpose is to demonstrate DFEC's multi-disciplinary engineering projects, support DFEC and DF events and STEM outreach. The intent is, R2-D2 must be designed for and have proper documentation allowing easy maintenance for 10 yrs.*

Detailed Description: *The cadets shall design, build, test, document, and deliver an R2-D2 for their capstone. The capstone does not have to determine part lifetimes and deliver spares to support R2-D2's operational lifetime of 10yrs. The key performance parameters (KPPs) described later are: safety, R2-D2's appearance, R2-D2 like interaction with people, and simple operations.*

Operational Scenario: *R2-D2 shall be capable of the following operating modes:*

1. **Standby mode:** *When R2 software is started, it will enter this state and remain until commanded to exit. No motor (servos, legs, or dome) are allowed to run. This state produces and is capable of recording telemetry. This state is the only state where charging will occur. When the power plug is connected, the robot will change from whatever state it is in to this one.*
2. **Remote controlled mode:** *When commanded into this state, the robot will except commands from the joystick. The commands will be followed except where sensor detect hazards and prevent the operator from damaging the robot (e.g., the operator cannot drive R2-D2 down stairs). In this state, all motors are enabled.*
3. **Static display mode:** *When commanded into this state, the robot acts like a robotic static display. The leg motors are not enabled; however the dome motor is able to move. This mode is entered either by a software command or external power supplied to the robot which will trigger relays and automatically cut power to the leg motors.*
4. **Autonomous mode:** *When commanded into this mode, the robot will autonomous move and avoid obstacles using its onboard sensors. When any issue arises (i.e., motor currents exceeded, loss of sensors prohibiting safe operation, etc) the robot will immediately go to standby mode. Also in this mode, R2 should be able to detect boundaries marked on the ground and treat them like obstacles (most likely black electrical/duct tape).*

¹ Complete all entries occupied by text in italics.

Additional modes may need to be developed depending on design.

R2-D2's Operations and Maintenance (O&M) shall be designed to be simple. R2-D2 shall charge off one charging cable that is easy to attach (see Episode IV, Luke Skywalker charging R2 on Tatooine, or Episode V on Degobah). Turning R2-D2 on or off, changing operating modes, driving, or any other operating function shall follow Apples motto: "it just works." Additionally, the assumption is parts may need to be replaced over the years, so everything needs to be accessible / modular for simple maintenance. Additionally, operation of R2-D2 is always safe, where on-board sensors ensure the user doesn't damage the robot or hurt anyone else due to carelessness.

Deliverables: *Cadets shall deliver a complete documentations package to support O&M:*

- *A fully operational/functional R2D2*
- *A fully operational/functional brass board of R2-D2 suitable as a hallway display*
- *Complete R2D2 specification*
- *All design trades*
- *All parts sources and costs*
- *A complete power and weight budget*
- *Detailed build instructions with pictures*
- *Document all hardware, software, and electrical interfaces*
- *All mechanical designs developed this year*
- *All electrical/board designs developed this year*
- *A complete description of Linux setup so the operating system can be redone from the standard Linux image should the system become corrupted*
- *All source code in a git repository and fully commented*
- *An operator's manual*

Specifications: *R2-D2 must meet the following specifications:*

1. *[KPP] R2 shall operate safely in all of the operating modes described above. Any loss of command or fault will automatically transition the robot into Standby mode.*
2. *[KPP] When the emergency stop (EMS) button is pressed, power shall be removed automatically to all motors (even under a fault condition that rendered the Linux computer inoperable), but all electronics shall continue to operate producing telemetry and status info.*
 - a. *The EMS shall be mounted approximately where R2's inhibitor switch is located in Episode IV.*
3. *R2's sensor suite shall allow:*
 - a. *Measure voltage and current at the leg motor batteries and electronics battery. When batteries are low, notify user and when a prescribed depth of discharge is reached, switch operating mode to standby until batteries are charged.*

- b. *Sense orientation and switch to standby if R2 has fallen down (exceeds a pitch or roll in excess of a predefined value). R2 shall also emit warning sounds and flash displays periodically (time interval is TBD) to indicate its need for assistance.*
- c. *Sense Earth's magnetic field, process the information into a heading (+/- 5 degrees), and use for navigation as needed*
- d. *Sense angle of dome in order to point the dome in a defined direction, (+/- 3 degrees)*
- e. *Sense the environment in front of it visually and be capable of:*
 - i. *Detecting faces in imagery (50% of time, with faces occupying 10 % of the image)*
 - ii. *Detecting scene change (i.e., someone entering a room) in static display mode (50% likelihood of detection)*
 - iii. *[objective] Recognize specified individuals (full list is TBD, but for ex: Darth Vader, Luke, Han) under ideal conditions. Note, these do not have to be real people, just images of them.*
 - iv. *Streaming (mjpeg) to any standards compliant web browser*
- f. *Measure distance travelled (odometry) to a resolution of 10cm across 5m.*
- g. *R2 shall sense stairs and drop-offs (or absence of floor) 180 degrees (threshold) or 360 degrees (objective) around it along the floor plane for safety*
- h. *R2 shall sense obstacles 180 degrees (threshold) or 360 degrees (objective) around it along the floor plane for safety*
- 4. *[KPP] While in static display mode, R2 shall sense the room and periodically interact with people passing by. The idea of "interacting" with people is TBD, but should in some way involve some or all of its capabilities: moving the dome, changing the displays, making sounds. The idea is to "entertain" visitors to the DFEC front office (or where ever R2 is put on display).*
- 5. *R2's interior shall be clean and designed to be presentation ready.*
 - a. *All cables will be routed and neat.*
 - b. *All electronics shall be neatly mounted*
 - c. *[objective] Interior lighting shall be setup to improve visitor inspection of engineering work*
- 6. *R2 shall have a modular design to support O&M*
 - a. *All cable shall have connectors for easy disconnecting*
 - b. *Design shall be modular and any interior component shall be removable for maintenance without having to cut, unglue, de-solder, or damage the robot in any way.*
- 7. *[KPP] R2 shall be returned to its proper appearance (as seen in Episode IV) with certain exceptions (e.g., emergency stop button) and some of the functions seen in the movies:*
 - a. *Holes in dome need to be filled in*
 - b. *Body needs to be re-assembled and outer structure (re)painted as necessary*
 - c. *Leg motors need to be hidden in the battery box*
 - d. *Front leg needs to be attached*

- e. *Skirt needs to be attached*
- f. *Leg covers/decorations need to be attached*
- g. *Leg and dome motors need to be properly mounted using the built in mounting holes*
- h. *Dome rotates 360 deg*
- i. *Dome doors open/close and TBD body panel doors via servos*
- j. *[objective] Leg thrusters for R2-D2 to fly with as seen in Episode II*
- 8. *R2 shall produce and record telemetry for testing and O&M:*
 - a. *Power, current, voltage on batteries, motors, and power distribution (5V, 3.3V)*
 - b. *Camera images*
 - c. *Sensor data (TBD until identified for remote control and autonomous operations)*
- 9. *R2-D2's will be filled with a lot of electronics that run hot, cadets shall make best effort to ensure proper cooling.*
- 10. *Human Machine Interface (HMI):*
 - a. *Telemetry: To aid in debugging/operations, HMI shall be defined for selected data and displayed/conveyed by R2 through a web server, display, sound, dome movement, or other method. The meanings shall be documented in the user manual of what these HMI mean.*
 - b. *[KPP] Operation: R2 shall be simple enough a 9 year old (or RPA pilot) can drive it (Remote Controlled Mode) or switch it into any other state. No command line ninja skills shall be required.*
 - i. *This may require more buttons, switches, or other HMIs to support this*
 - c. *In remote controlled mode, R2-D2 shall be driven via a wireless Bluetooth joystick connected directly to R2-D2*
 - d. *R2-D2 shall support connecting to a local Ethernet (this needs to be easily accessible to user) or wifi network.*
 - e. *R2-D2 shall provide its own wifi network, so users/visitor can connect directly to it and view telemetry or other interesting data (video stream), movie clips*

Constraints

- 1. *R2-D2 shall operate off a 12V power system (for distributing power and charging). Buck converters shall lower the voltage to support other voltage levels*
- 2. *R2-D2 shall be designed to operate in doors (smooth floors, handicapped ramps, temperature controlled) or outside under ideal conditions (not all-weather, roads/sidewalks, 70 degree F, no bad weather)*
- 3. *In Static Display Mode, R2-D2 shall be run off external 12V power (wall wart) plugged into a standard power outlet. The external power only runs the equipment in this mode and the leg motors are disconnected to prevent accidental activation*

Equipment/Data/Software Furnished: *DFEC has already developed a reference design and purchased a variety of parts to support that reference design. Additionally, key hardware was purchased for the project in 2010 that is furnished.*

Software, either designed specifically for this project or useable by this project is listed here:

- <https://pypi.python.org/pypi/ttastromech>
- <https://github.com/MomsFriendlyRobotCompany/mote>
- <https://pypi.python.org/pypi/nxp-imu>
- <https://pypi.python.org/pypi/mcp3208>
- <https://pypi.python.org/pypi/fake-rpi>
- <https://pypi.python.org/pypi/smc>
- <https://pypi.python.org/pypi/pysabertooth>
- <https://github.com/DFEC-R2D2/r2d2>

Resources: *Unfortunately, AY 16-17 R2-D2 program was a disaster, with no recoverable design, software, or hardware. The following resources are for guidance only:*

- <http://astromech.net> (need to make an account)
- <http://2geekswebdesign.com/astromech/>
- <http://www.artoo-detoo.net/>