Understanding the Rotormast V-22 Osprey

Design methodology

The real V-22 Osprey is a complicated machine, but without the need for extreme reliability associated with manned flight, significant simplifications can be made that make this model possible. The Rotormast V-22 sophisticated controller was designed to reduce mechanical complexity; in addition, the ship takes advantage of the inherent simplicity and reliability of electric motors to further simplify the design. Collective and cyclic pitch controls are used to give positive control for hover mode and its control power is also utilized in transition and airplane mode to eliminate the need for traditional fixed wing control surfaces. Three gyros are used to stabilize the aircraft to eliminate the mechanical complexity of a fly bar system and allow the use of a 3 bladed head to add scale realism and performance. The basic Rotormast V-22 is designed around a self supporting structure with bolt on non-structural scale covers that allow for both scale and non scale flight. The Rotormast V-22 Ospreys clever design makes a scale model of a VTOL aircraft possible without much more complication than any typical scale model helicopter.

Mechanical simplification features

- No mechanical connections between nacelles
- No cross shafting
- Independent conversion mechanism
- No conventional airplane controls
- No lateral cyclic control
- No fly bar system
- 2 cyclic servos/swash plate
- Direct CCPM connection of servos to swash plate
- Symmetric blades
- Bolt on scale body covers

Control methodology

Control stick functions and transmitter setup is similar to any model helicopter, with the left stick performing the collective pitch and yaw function and the right stick performing pitch (nick) and roll functions. Also the typical helicopter functionality of Stunt N, 1, 2 and throttle hold are used to control the throttle. In addition to the conventional helicopter controls a nacelle position slider or knob is necessary to control conversion angle. Other than the very basic helicopter transmitter functions such as collective pitch curves, throttle curves, servo directions and volumes most of the models setup is performed in the Rotormast V-22 Controller utilizing a USB PC connection and the Rotormast V-22 Configurator software. Setup is similar to any model helicopter other than swash plate movement are different because of the twin rotor configuration and the additional steps necessary for successful conversion flight.

In **helicopter** mode swash plate movements are:

- Roll is accomplished with differential Collective Pitch of both swash plates
- Pitch is accomplished with For/Aft tilt of both swash plates
- Yaw is accomplished with differential For/Aft tilt of both swash plates
- Vertical control is accomplished with symmetric Collective Pitch change of both swash plates

Servos
For/Aft Cyclic and Collective Pitch is all that is necessary to control a tilt rotor aircraft. This is possible with only two servos per swash plate. It is also possible to take advantage of cyclic and collective pitch control in airplane mode to eliminating the need for conventional airplane controls if the yaw and roll controls are swapped during the conversion. The Rotormast V-22 controller has its own CCPM mixer that allows direct drive of the swash plates to eliminate the need of a mechanical mixer. The swash plates require precise control typically associated with digital servos.

Speed controllers
Speed controllers with governor mode are used to keep both rotor RPMs balanced and constant during the entire flight. For high reliability and precise control of rotor RPM a high quality speed controller with governor mode is recommended.

Conversion flight
The V-22 controller performs all the control mixing necessary to make the ship react the same as any typical model airplane during the conversion flight. With the left stick performing speed and rudder function and the right stick performing the elevator and aileron function. The transition between airplane mode and helicopter mode is seamless, allowing the V-22 to be flown at any conversion angle with no exceptional pilot skills. As the ship converts into airplane mode, the V-22 controller performs several functions to provide precise continuous control of the Rotormast V-22 with no additional pilot work load other than selection of the conversion angle. During a conversion the controller will:

- Adds collective pitch to allow the ship to accelerate in conversion flight
- Swaps roll and yaw controls to make pilot inputs consistent thru conversion flight
- Adjust servo volumes to keep the feel of the ship consistent to the pilot
- Adjusts gyro gains to keep the feel of ship consistent to the pilot
- Monitors Motor RPM and adjusts collective pitch to match airspeed

As a conversion takes place the **helicopter** mode controls described above transform into **airplane** mode control

- Aileron is accomplished with differential For/Aft cyclic of swashplate
- Elevator is accomplished with For/Aft tilt of both swash plates
- Rudder is accomplished with differential Collective Pitch of both swash plates
- Speed control is accomplished with symmetric Collective Pitch change of both swash plates

RPM monitoring
The Rotormast V-22 Controller is equipped with special circuitry to allow monitoring of each rotor RPM. This is done for a several reasons:

- Improve the reliability of the electric power system by monitoring RPM to prevent a bog that will result in an overload of the power system. If a Bog is detected on one or both rotors the controller will reduce collective pitch and allow both rotors to recover RPM.
- If rotor RPM becomes unbalanced the controller will reduce collective pitch of both rotors to allow the slow rotor to recovers and maintain a balanced system.
- When the ship is at high power settings during conversion flight the controller is set up to over control collective pitch, engaging the pitch governor, the pitch

governor will then sense a reduction in RPM and adjust the CP as necessary to prevent slowing of the rotor. This will set the proper collective pitch for any given airspeed and allow CP to increases as airspeed increases improving the top speed of the model.

Stability
Three Gyros are used to stabilize pitch, roll and yaw, the gyro signals are fed from the gyros into the controller and are applied to the appropriate servos depending on the nacelle angles, The gyro operate in all flight modes but their gains are adjusted by the Rotormast V-22 controller as the ship performs a conversion. For this reason the gain setting is not controlled by the transmitter as in a conventional model helicopter and the gain switch on the transmitter is only used to swap between the hold and rate mode on the ground. For rock solid stability only uses high quality MEMS HH gyros with remotely adjustable gain.

Wiring
Two sets of power wires are used to take both batteries power to the speed controllers in each nacelle, the right and left power wires are joined to keep power matched. The power wires have a BEC plug if the fuselages mounted BEC is used. There are 3 conventional servo extension wires running out each wing but only one, the conversion servo extension, carries the standard power and servo signal. The Nacelle Signal extension (yellow) only caries the servo singles for the ECS, Forward and Aft servos. The Nacelle Power extension (red) carries positive 5.5 volts to run electronics, ground and the RPM signal used by the controller. Mixing up the red and yellow extension wires will result in damage to the Rotormast V-22 Controller.

Conversion actuator
The conversion servos are independent adding to the simplicity of the model. The conversion servos are modified standard digital servos with the pot and output gear stop removed. The potentiometer is directly connected to the nacelle allowing the conversion servo to rotate several times during a conversion significantly increasing the holding power of the system. Because of servo inconsistencies the Rotormast V-22 Controller has functionality to match the right and left conversion servos through the entire conversion envelope. The Rotormast V-22 Controller also slows the conversion speed to allow for a smooth conversion independent of the switch operation.

Scale model
The Rotormast V-22 model basic kit is a profile model that utilizes scale covers for quick and easy adaptation to the scale model. This allows all set up, training and test fights to be accomplished with full access to the aircraft electronics and mechanics.

Rotormast V-22 Controller

The V-22 controller is the heart of the model, it performs several functions that make the model fly no different that any typical model helicopter in helicopter mode and like any typical airplane model in airplane mode.

Power management

There are 2 possible electronics power options available:

EXTERNAL BEC (**Option one**)

An external fuselage mounted BEC (5A min) can be used to power the electronics. There is a plug added to the power wires for this purpose. The BEC output plug is then connected into the receiver battery port and the BEC jumpers are removed from the Nacelle wire distribution boards. In this configuration the fuselage mounted BECs will power the Rotormast V-22 electronics and power flows out the wing through the Nacelle Power wires.

INTEGRATED ECS BEC (**Option two**)

If the BEC integrated in your brushless speed controllers are capable of working with a 4 cells lipo batteries and have at least 3A capability each, they can be used to power the ships electronics. In this configuration the Nacelle wire distribution boards BEC jumpers are plugged in and ECS's integrated BECs will share the load to power the ship. Note: The controller contains special circuitry that allows simultaneous use of integrated BECs. In this configuration the speed controller BECs will power the Rotormast V-22 electronics and power flows toward the fuselage through the Nacelle Power wire.

Other functionality

The controller performs several functions to allow operation of the Rotormast V-22 Osprey with only a 7 channel transmitter and standard electric model components

- CCPM MIXER: Allows direct drive of the swash plate by the servos to control For/Aft cyclic and Collective Pitch
- YAW/Pitch Mixer: Swaps yaw and pitch control with changing nacelle angle to allow cyclic control of the aircraft thru the entire conversion envelope including airplane mode thus allowing elimination of conventional airplane controls.
- Conversion controller: Slows speed of conversion servo, allows matching of RH and LH conversion servos to keep nacelles angles matched
- CP governor: Modulates CP to prevent a bog and an overload of motors to add reliability to system and adds collective pitch as airspeed increases to maximize forward speed in airplane mode
- Volume Control: Adjusts volume of roll pitch and yaw inputs with changing nacelle angle to give the ship a consistent feel thru the conversion and into airplane mode
- Gain Controller: Adjusts gain settings with changing nacelle angle to give the ship a consistent feel thru the conversion process and also will allow gyros to be switched from hold mode to rate mode for any given nacelle angle if the pilots discretion.
- Pitch Shift: Adds collective pitch with increase in conversion angle to over control the collective pitch engaging the pitch governor