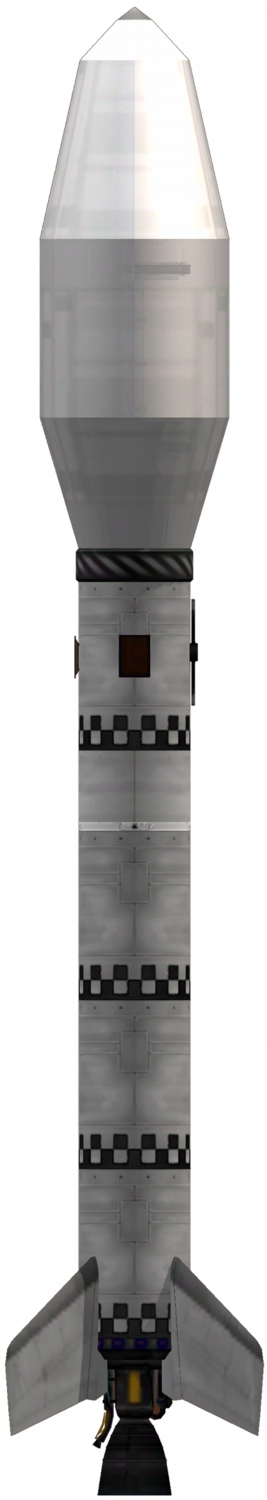
Kerman Space Systems

R-3 Series of Carrier Rocket



Operator’s Manual

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R-3 family description

The R-3 rockets are 2 stage rockets designed as a payload carrier for ground to low Kerbin orbit. These rockets are designed to deliver a payload of up to 3.2 tonnes to an 80 KM circular orbit.

The rocket comes with a standard payload section, simplifying performance calculations. The only relevant parameter for performance calculation for a specific fairing type is payload mass.

Vehicle coordinate data

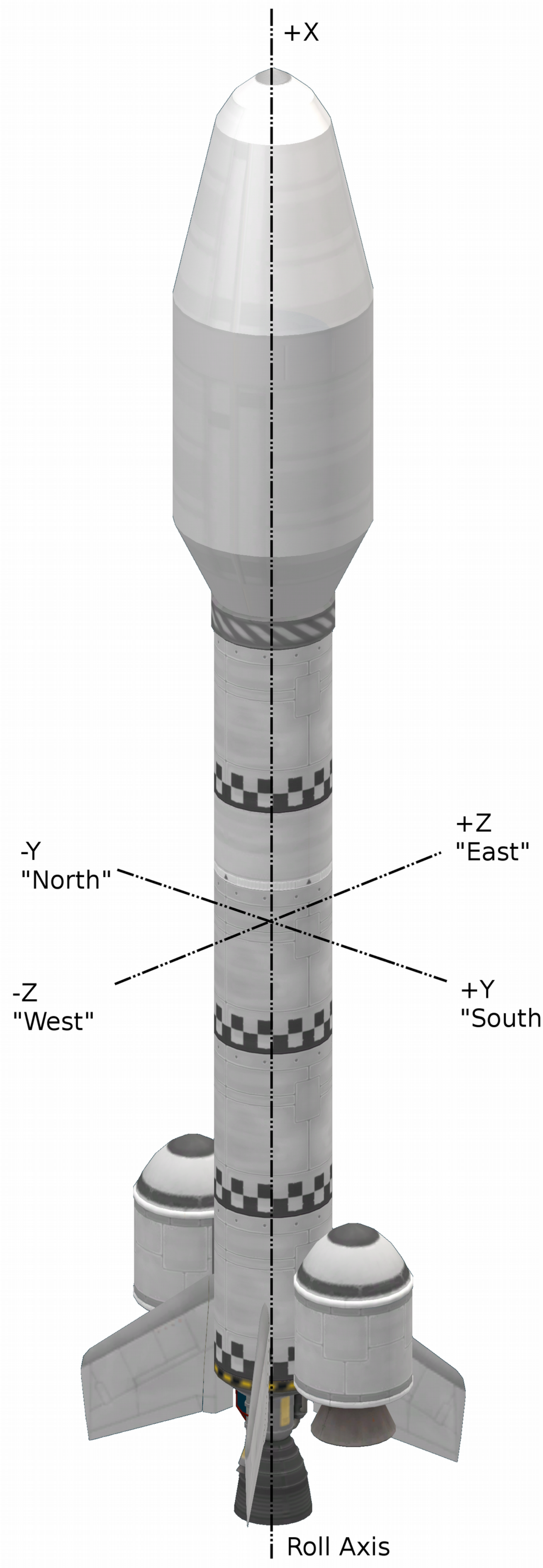
The launch vehicle coordinate system is comprised of three axes. Using these axes, directions can be unambiguously referenced in this manual.

The X axis runs along the body of the rocket. It is also known as the roll axis. A clockwise movement, as seen into the vehicle's nozzles is defined as a "right roll", while the opposite roll is defined as a "left roll". These movements correspond to the input controls and the response of the navball.

The two remaining axes delimit the sides of the rocket. The Z axis defines the left and right sides. Rotating over the Y axis, causing the nose to point to the +Z direction is called a "right yaw" while the opposite movement is a "left yaw". Rotating over the Z axis to point the nose to the +Y direction is a "pitch up" maneuver, while the opposite is a "pitch down". These movements correspond to the yaw and pitch movements caused by acting on the respective controls and the corresponding navball response.

Additionally, the +Z side is called the "east" side, the -Z side is called "west" and the +Y and -Y are called "south" and "north" respectively. These shorthand definitions correspond to the cardinal directions faced by each side, when sitting on the pad waiting to launch, and is used to identify each upper stage hardpoint.

The +Z and -Z sides are also called the "right" and "left" side during the autopilot program descriptions.


+X
+Z
"East"
-Y
"North"
-Z
"West"
+Y
"South"
Roll Axis

R-3 series ID codes

R-3 rockets are identified by the following alphanumerical code.

```
R3-(400,800,1200,1200B,1200L)-(F,C,S,D)(1,2,3,4,5)-(N,O,J,H)(0,1,2)(0,1)
(N,O,P,Q)(0,1,2)(X,R)
```

These codes describe the features of each specific rocket type and should be interpreted in the following way.

```
R3-(Type)-(Payload Section)-(Avionics)
```

The R3 string defines the base rocket family. Strings other than R3 represent different rocket families, specified in other documents. This identifying string is left constant for all members of this launch vehicle family.
The type defines which specific member of the R-3 family is being described. There are 5 members of the R-3 family.

Rocket type code	Description
400	Ultra short launch vehicle, for very light payloads
800	Shorter launch vehicle
1200	Baseline launch vehicle
1200B	Boosted 1200 model, two solid fueled boosters
1200L	Booster 1200 model, two liquid fueled boosters

The payload definition is a two letter code describing the arrangement of payload bay and fairing type. The payload bay definition comes first, followed by a fairing definition.

Bay code	Description
F	Payload affixed to fairing base, integral to upper stage
C	Capsule service module, no avionics bay
S	Single payload with avionics bay
D	Dual payloads with avionics bay

The fairing definition is shown below.

Fairing code	Description
1	Kerman Space Systems fairing type A1
2	Kerman Space Systems fairing type A2
3	Kerman Space Systems fairing type A3
4	Kerman Space Systems fairing type B1
5	Kerman Space Systems fairing type B2

Types 1 to 3 fairings are used for general cargo, while fairing types 4 (B1) and 5 (B2) are used for manned capsules. Rocket type C4 has been designed with the AOC-3 capsule in mind, while type C5 is suited for launching the AOC-2 capsule. See their respective manuals for details.

Immediately after the payload section definition comes the avionics description code. This code describes the launch vehicle's avionics. Each letter describes a particular system, and has several variants described in the table below. Avionics are mounted in the avionics bay inside the fairing or in 4 hardpoints, radially, connected to the upper stage fuel tank.

System	Code	Definition
On board computer	N	No OBC. Guidance depends on payload computer.
	J	MechJeb2 AR202 case in west upper stage hardpoint.[1]
	O	Probodobodyne OKTO in payload bay.
	H	Probodobodyne HECS in payload bay.
Stabilization	0	No reaction wheels, except as provided by OBC.
	1	Small reaction wheel in avionics bay.
	2	Advanced Inline Stabilizer in avionics bay.
Communications	0	Payload communications only.
	1	Communotron-16S in east upper stage hardpoint.
Power generation[2]	N	No power supply, power provided only by batteries.
	O	2 OX-STAT solar panels radially attached to north/south sides.
	P	1 OX-STAT solar panel radially attached to west side.
	Q	Model O and P panels.
Power storage	0	On board computer and payload batteries only
	1	Z-200 battery bank in avionics bay
	2	Z-1K battery bank in avionics bay
Reusability	X	Expendable.
	R	Single MK16 parachute in avionics bay.

1 Requires MechJeb plugin to work.
2 P and Q power systems are not compatible with J type computers.

R-3 rocket assembly

R-3 rockets should normally be taken from a template, resorting to manual assembly only if a template is not available. The use of a template ensures consistency in performance and physical characteristics.

After manual assembly and testing of an R-3 model, we recommend saving the result as a template.

Boosted variants should be extensively tested to ensure proper booster aerodynamic characteristics during ejection.

Lower stage

Sustainer core assembly

Take a LV-T30 “Reliant” liquid fueled engine and place in the VAB building. Ensure that it is set to full thrust.

Take the necessary number of “dark” themed FL-T400 fuel tanks (1 for the R-3-400, 2 for the R-3-800 and 3 for the R-3-1200) and stack them axially above the engine, one above the next. Other types of fuel tanks are not recommended, as using the same tank type for all variants simplifies the conversion between models and other tank models may also lack important markings used in as reference during assembly.

Take a TD-12 decoupler and stack axially above the topmost fuel tank.

Sustainer fin installation

Fin assembly should be done using 4-way radial symmetry. The installation should be done simultaneously on all 4 fins, and manual installation (one at a time) should not be used.

Under 4 way symmetry, take one AV-R8 Winglet. Using snap to position and 4 way symmetry, place four fins on a 45 degree angle to the Y and Z axes (cardinal directions NE, NW, SE and SW).

Illustration 1: High contrast picture of fin section, with reference extension line.

The fin height should be adjusted to match the picture to the right. As reference, when the fin position is correct, a line projecting from the short structural reinforcement above the middle full length one should intersect the first point (defined by the intersection of the square markings in the fuel tank) after the fin. The reference line should then intersect the top of the pattern, at the point between the one of the top-most squares that defined the first point, and the square immediately to the Z or Y axis.

Fins should be configured with a 30% control authority.

Booster decoupler installation

For boosted models, it is necessary to install radial decouplers that will act as support points for the boosters. The decouplers should be installed on the north and south sides using 2 way radial symmetry.

Using 2 way symmetry and angle snap, take a TT-38K radial decoupler and place over the north or south side. The decoupler should be mounted with the centre intersecting the plane defined by the X and Y axes. The FL-T400 tank has a seam in the position where the decoupler should be installed. This seam is interrupted at the top and bottom, as seen in the picture to the right.

Decoupler position along the rocket length can be easily determined by using the checker markings. The lower explosive bolt should be centred at the white square at the +-Y position.

Only R-3-1200 cores should be boosted. Boosting is not an option for R-3-400 and R-3-800 rockets.

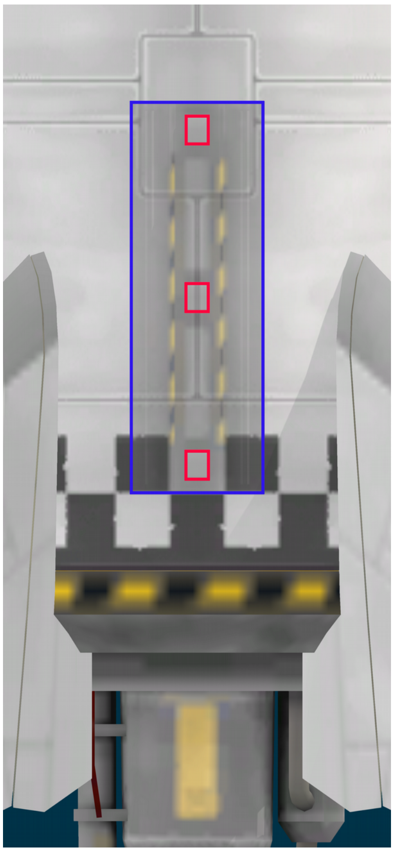


Illustration 2: Booster decoupler installation. Footprint highlighted in blue. Explosive bolts in red.

B1 solid fueled booster installation

The B2 solid booster is built upon the RT-5 “Flea” solid rocket booster engine. The only other component is an aerodynamic nose cone.

Assembly is normally done by connecting a RT-5 solid engine to the lower stage decoupler. The decoupler should be installed over the full length of the fuel tank of the RT-5. The booster should be installed centred and the top of the decoupler should be over the grey line at the top of the fuel tank.

Once the booster is installed, the nose cone can be axially attached at the top.

The engine should then be configured to deliver 63% of the full thrust for use in the R-3 family.

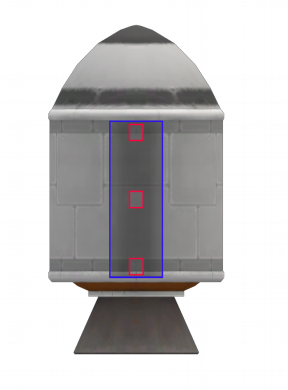


Illustration 3: B2 booster. Decoupler footprint in blue, explosive bolts in red.

L30-400 liquid fueled booster installation

The L30-400 booster is composed of a LV-T30 “Reliant” engine with a FL-T400 fuel tank and a basic nose cone on top. These components should be assembled axially.

To assemble a booster from individual components, connect a FL-T400 fuel tank to the lower stage decoupler. Immediately connect the nose cone and the engine to the fuel tank’s axial connectors.

Once the booster is assembled, move it along the radial decoupler until the top of the decoupler ends exactly at the riveted structure at the top of the tank (see picture to the right).

Once installed, set the engine thrust to 56% of maximum. This setting applies only to the R-3 family, other rockets may use a different configuration.

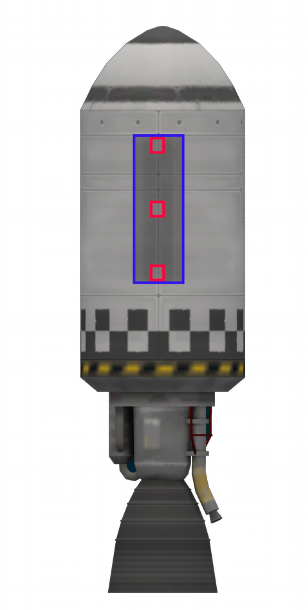


Illustration 4: L3-400 booster. Decoupler footprint in blue, explosive bolts in red.

Upper stage

The R-3 family uses a single type of upper stage. This upper stage is powered by a LV-909 “Terrier” engine and fueled by a single FL-T400 liquid fuel tank.

The upper stage has 4 hardpoints in which additional equipment can be installed.

Upper stage core assembly

Upper stage core assembly is straightforward. Simply place a FL-T400 fuel tank over a Terrier engine axially. The engine should be set with a full thrust configuration.

Upper stage hardpoints

The upper stage has four hardpoints for external mounted avionics. The only external avionics currently available are the Communotron 16-S, OX-STAT solar panels and MechJeb’s AR202 case.

The communitron antenna should be mounted vertically, spanning the entire height of the three central panels. Its footprint is marked in black in the picture to the right.

Illustration 5: Upper stage hardpoint, showing footprint for OX-STAT solar panel and Communotron 16-S antenna.

The OX-STAT and AR-202 should be mounted immediately below the junction of the third to fourth panels, counted from the top, using the yellow footprint as a guide.

Both should be mounted using angle snap, with an orientation towards the cardinal points.

It should be noted that in the north and south faces of the rocket, the junction to be used as reference is partially interrupted by a square panel. The junction is present at the right and left sides of the hardpoint and should be used as a guide for mounting, ignoring the panel.

Payload section

Payload sections should be taken as-is from the KSS catalogued fairings.

LV type	Fairing	Mass	Uses
1	A1	329	General cargo, short fairing.
2	A2	424	General cargo, long fairing.
3	A3	491	General cargo, extra long fairing.
4	B1	267	AOC-3 launch.
5	B2	323	AOC-2 launch.

Cargo bays should also be configured as indicated in the fairings and cargo bay catalog. The following definitions are used in the R-3 family.

Cargo bay code	Description
F	Empty fairing, payload affixed to fairing base.
C	Capsule service module. Decoupler affixed to fairing base, capsule follows.
S	Single bay, as specified by catalog.
D	Dual bay, as specified by catalog.

Payload mass calculation

Payload mass should be corrected to account for the differences in avionics in each rocket model. Payload mass is calculated and tabled based on a baseline model (F1-N00N0X) and the following adjustments should be made for each variation.

Type	F	+0 Kg
	C	+40 Kg
	S	+40 Kg
	D	+80 Kg
Computer	N	+0 Kg
	J	+0 Kg
	O	+100 Kg
	H	+100 Kg
Stabilization level	0	+0 Kg
	1	+50 Kg
	2	+100 Kg
Communications	0	+0 Kg
	1	+15 Kg
Power generation	N	+0 Kg

	O	+10 Kg
	P	+5 Kg
	Q	+15 Kg
Power storage	0	+0 Kg
	1	+10 Kg
	2	+50 Kg
Recovery	X	+0 Kg
	R	+100 Kg

Example

A 500 Kg satellite is being launched in the single payload bay of an R3-1200-S1-H11O1X launcher rocket. The following adjustments should be applied to the payload mass.

Type S, single bay shrouded: add 40Kg to mass.
Type H computer: add 100Kg to mass.
Stabilization level 1: add 50Kg.
Level 1 communications: add 15Kg.
Battery level 1 (Z-200): add 10Kg
Dual solar panels (type O): add 10 Kg.
Expendable rocket: no mass added.

Total corrections: 225 Kg.

Adding 225 Kg to the payload mass of 500Kg yields a 725 Kg payload. All calculations with respect to autopilot and mass parameters should be based on a 725 Kg payload (500 Kg effective payload + 225 Kg avionics). As an additional check, the zero point (corresponding to an empty R3-1200-F1-N00N0X rocket) for a regular R-3-1200 corresponds to a mass of 11.614 tons. Any mass above that number should be entered considered as payload (either avionics or effective payload).

Base Type	Empty mass (tonnes)
R3-400-F1	7114
R3-400-F2	
R3-400-F3	
R3-800-F1	9364
R3-800-F2	
R3-800-F3	
R3-1200-F1	11614
R3-1200-F2	
R3-1200-F3	
R3-1200B-F1	14724
R3-1200B-F1	
R3-1200B-F1	

R3-1200L-F1	18724
R3-1200L-F1	
R3-1200L-F1	

R-3 rocket family performance data

Payload characteristics (fairing type 1)

Parameter	R3-400	R3-800	R3-1200	R3-1200B	R3-1200L	Unit
Minimum payload mass	450[3]					Kg
Maximum payload mass	770	1450	2100	2580	3200	Kg
Maximum fairing diameter						cm
Minimum fairing diameter						cm
Fairing length						cm
Nose cone height						cm
Nose cone diameter						cm
Avionics bay height						cm
Avionics bay diameter (min)						cm
Avionics bay diameter (max)						cm
Lower payload bay diameter (min)						cm
Lower payload bay diameter (max)						cm
Lower payload bay height						cm
Upper payload bay diameter (min)						cm
Upper payload bay diameter (max)						cm
Upper payload bay height (with nosecone)						cm
Upper payload bay height (w/o nosecone)						cm

3 Rockets with level 2 stabilization work with just the wheel as payload, for a minimum payload of 100Kg,

Payload integration

Once the rocket is assembled, the payload should be integrated into the stack. Integration in its simplest for is just taking the payload (or payloads for dual launches) and attaching it to the payload bay decoupler.

The rocket comes with TD-12 payload decouplers. The rounded nature of the type 1 fairing may require customization of the payload bay or use of adapters to prevent some types of cargo from colliding with the fairing. The following strategies are recommended.

1. Moving the payload bay decouplers, which alter the truss structure
2. Removing the TD-12 decoupler and connecting the payload using an adapter
    1. A FL-A10 adapter with a TD-06 decoupler on top
    2. A FL-A5 adapter with a TD-06 decoupler on top
    3. A modular girder adapter with a TD-06 decoupler on top

Weight saving measures can be implemented in the payload integration phase. These involve minor modifications to the payload interface with the rocket.

1. Replacing the TD-12 decoupler with a TD-06 one, entails a reduction of 30Kg per replacement.
2. Using the modular girder adapter, with a reduction of 5 Kg.

Payload decouplers may be replaced by separators, at a small mass penalty (10Kg per separator). Separators create debris during operation, and are not recommended for payload launches in orbit. If a separator is to be used, replace the upper bay decoupler with one, and readjust the lower bay decoupler’s ejection force to 100. Use of separators in the lower payload bays is not necessary.

Ascent

Multiple ascent profiles are available, depending on the techniques available and the desired precision and ease of use.

MechJeb 2 ascent

MechJeb, if available, is the simplest ascent mode. It is also fully automated and may not be desirable in certain cases. Moreover, it is not as precise as a properly executed SAS or manual ascent.

To execute a MechJeb ascent, select the ascent program “Stock style gravity turn” and program the following parameters.

		R-3-1200	2L30-400
TARGET	Orbit altitude (Km)	80	80
	Inclination (deg)	0	0

GUIDANCE	Turn start altitude (Km)	0.5	0.5
	Turn start velocity (m/s)	50	35
	Turn start pitch	see table below	see table below
	Int. altitude (Km)	80	80
	Hold AP time (s)	1	1
OPTIONS	Prev. engine ovrheat	No	No
	Limit Q (Pa)	No	No
	Limit Accel (m/s^2)	No	No
	Keep limited throttle (%)	No	No
	Electric limit (%)	No	No
	Force roll climb-turn	90-90	90-90
	Limit AOA (deg)	5	10
	Dynamic pres FO (Pa)	2500	2500
	Autostage	Yes	Yes
	Autostage delay, pre (s)	0.5	0.5
	Autostage delay, post (s)	1	1
	Clamp autostage thr (%)	0.99	0.99
	Stg frings, dyn prs (KPa)	5	5
	Stg frings, altitude (Km)	50	50
	Stg frings, flux (W/m^2)	1135	1135
	Stop at stage[4]	1 for single 2 for dual	1 for single 2 for dual
	Auto deploy solar panels	No	No
	Auto deploy antennas	No	No
	Auto warp	No	No
	Skip circularization	No	No

Other parameters should be left with their default values. All orbital and guidance parameters define how orbital insertion is done and should not differ from the data above.

The “stop at stage” parameter is set to exclude the payload staging. This is done to prevent premature ejection of inert payloads by MechJeb once the payload fairing is opened. If anything other than single stage payloads (e.g. payloads with kicker rockets) are placed in the payload bays, adjust the “stop at stage” value to one stage before the first payload decoupler (as a rule of hand, this is usually the stage number of the payload fairing).

The auto deploy options are set to false to prevent damage to the rocket and/or payload due to deployment inside the payload bay. This is especially true for lower payloads, and not critical for

4 Assumes single payload with no additional staging in each bay. Fully read this section and adjust properly if that is not the case.

single or upper payloads. These switches may be toggled if it is determined that antenna and/or panel deployment will not interfere with proper operation of the spacecraft.

The initial gravity turn pitch should be decided taking the payload mass into account. For each payload mass, there should be an optimal angle, which minimizes propellant use. This angle has been recorded in the table below. Next to this value are the 99% efficiency values. This values show the maximum and minimum angles that yield 99% of the delta V of the optimal angle. The outer values of the pitch angle table show the “never exceed” values. These are the hard limits of the gravity turn. Any attempted gravity turn that exceeds these values will likely cause the spacecraft to fail to orbit. Some of these failure modes are not correctable, and may not be immediately obvious.

Pitch table for R-3-1200 rocket				
Payload (Kg)	Pitch, Minimum Never exceed	Pitch, steepest 99% dV efficiency	Pitch, optimal	Pitch, shallowest 99% dV efficiency
500	5	15	20	30
1000	11	14	18	23
1500	10	13	15	19
2000	7	13	13	13

Pitch table for R-3-1200-2L30-400 rocket				
Payload (Kg)	Pitch, Minimum Never exceed	Pitch, steepest 99% dV efficiency	Pitch, optimal	Pitch, shallowest 99% dV efficiency
2000				
2500				
3000				
3400				

Note how optimum angles become shallower, and margins decrease as payload mass shifts closer to the launcher’s maximum rated values. For details, see a comprehensive list of launch experiments in page 28.

All ascent calculations executed on a test model (indicated in the variants table) with inert payload and corrected to effective payload using the payload calculation procedure.

SAS assisted ascent

SAS assisted launches are available for the case when MechJeb is unavailable or undesirable. This mode consists of doing a gravity turn, similar to Mechjeb's, followed by a coast to apoapsis and circularization burn.

Note: the proper pitch angle tables have not yet been experimentally determined. To select a pitch angle, take the optimal angle for the payload mass from the MechJeb ascent and subtract 2.5 degrees.

The ascent program for SAS assisted launches is shown below.

1. Turn on SAS on stability assist mode
2. Set throttles to 100%
3. Activate the staging sequence to launch
4. If necessary, rotate rocket so that the pitch-down side faces the desired orientation
    - Note that this is usually done on the starboard side, which is already pointing to 090 degrees (due east)
5. Wait until speed relative to surface reaches 50 m/s for R-3-1200 or 35 m/s for R-3-1200-2L30-400
6. Initiate a hard pitch, watch the velocity vector and wait until it reaches the desired angle
    - The winglets are calibrated as to prevent over-pitching when actuated at their maximum deflection
7. When the velocity vector reaches the desired angle, set SAS to prograde mode
    - Alternatively, temporarily disable SAS and release controls to allow the winglets to passively stabilize the rocket. Activate prograde mode before activating the upper stage or at 10000 metres at latest.
8. When propellants run out, activate the second stage, cutting thrust as soon as apoapsis reaches the desired altitude (usually 80 Km)
    - If apoapsis reaches the desired altitude before first stage cut-off, the climb was too steep. Consider aborting the mission or taking emergency action. Orbit may be achievable with light payloads. Consult the test data.
    - Alternatively, wait until apoapsis reaches 5km below intended orbit and reduce burn to minimum, adjusting altitude by actuating throttle during coast, if a single long burn is desired.
9. Coast to apoapsis and wait until the tabled time for the current velocity, then set the throttle to 100%. Reduce throttle as apoapsis is pushed back. Try to keep the apoapsis time to close to 5 seconds. Do not pass apoapsis.
10. Cut off upper stage engine when periapsis reaches intended altitude.

SAS ascent circularization table (80 Km orbit)							
		Orbital velocity at apoapsis					
		1000	1250	1500	1750	2000	2250
Payload mass	500						
	1000						
	1500						
	2000						
	2500						
	3000						
	3400						

To use the table above, take the velocity as the upper stage reaches apoapsis and take the corrected payload mass (payload + avionics). Execute a full thrust prograde burn at the indicated number of seconds before apoapsis. Do not retard throttles until apoapsis is pushed away as orbital velocity is reached. During throttle retardation, keep the time to apoapsis as low as possible.

Hybrid ascent

The hybrid ascent combines the first part of the Mechjeb ascent with the circularization burn of the SAS ascent. This is particularly useful at the limits of Mechjeb ascent guidance capabilities. To execute a hybrid ascent follow the procedure below.

1. Execute a MechJeb ascent until the Kerman line[5] is reached.
2. Disable MJ2 autopilot.
3. Enable SAS prograde mode.
4. If the payload fairing has not been ejected, eject it.
5. Wait until the time for the circularization burn is reached, and execute a SAS circulatization.

Manual ascent

Manual ascent is identical to the SAS assisted burn with the following changes. This method is used when prograde mode is not available (e.g. with AR202 or OKTO computers).

1. If SAS stabilization is available and used for turn, disable SAS after reaching the desired pitch.
2. Let the fins stabilize the spacecraft until the first stage is jettisoned.
3. Manually follow the prograde marker during second stage ascent, using any means available for that purpose.

5 Defined as 70Km over Kerbin surface. https://en.wikipedia.org/wiki/K%C3%A1rm%C3%A1n_line

4. Once the coasting phase is reached, take time to estimate circularization burn direction. After 60 Km altitude is reached, orient the spacecraft in the burn direction, as late as possible.
    - After 70 Km, drag is negligible and the spacecraft should be reoriented regardless of time to apoapsis.
5. Execute a SAS-style circularization burn.

Payload ejection

Payload ejection for single launches should follow the standard procedure. Payloads are ejected using a decoupler, which applies a separation force. This applies to upper payloads in dual launches.

The lower payload of a dual launcher utilizes a zero ejection decoupler system and must be maneuvered out of the payload bay. There are several approved procedures.

1. If the payload has RCS, apply a lateral translation burst to move it from the payload bay.
2. If the payload has no RCS, but reaction wheels and a station keeping engine, rotate payload and apply thrust to clear the payload bay. Payload may bump into upper bay or lower bay supports.
3. If payload engine fails, rotate the rocket after decoupling using the rocket's reaction wheels (if available).

Bumping the payload bays during payload rotation may induce translation that could get a payload out of the bay, but this should be regarded as an emergency procedure only. Damage to payload or carrier rocket may occur if this procedure is used.

C type models are used as capsule service modules and should not normally be decoupled from the payload, as the capsule may need the module for propulsion. Ejection of C type upper stages are normally done after the final reentry burn. Read the capsule manufacturer's documentation for the recommended procedure.

Deorbit burn

Most variants of the R-3 rocket have a flight computer and a small amount of battery capacity (or solar panels) to permit deorbiting of the spent upper stage once payloads are delivered. The procedure varies depending on the avionics and control systems available.

Deorbit procedures should commence as soon as the payload is released. Basic models have a AR202 computer with limited (5 unit) battery capacity. More advanced models have solar panels and larger batteries that extend the useful life of the rocket, allowing the execution of the deorbit burn at later, more convenient, times.

Combination deorbiting and inclination change

If the mission involves delivering payloads to a highly elliptic orbit with an inclination change, the burn may be executed at the node after periapsis, trading inclination for periapsis altitude. This type of burns leave the spacecraft in a suborbital trajectory, which requires the payload to complete its insertion burn at apoapsis or risk reentry.

The same technique can be applied during orbital operations without inclination change, but this usually requires the payload to execute its insertion burn immediately after release, which may not be desirable.

Direct deorbiting

The usual mode of operation consists of executing a deorbit burn after delivering a payload to a circular low Kerbin orbit. This requires the rocket to turn to retrograde orientation and execute a burn using the remaining propellants.

The method of executing the turn depends on the control systems available. For models with reaction wheels, or OKTO and HECS computers the procedure consists of turning to retrograde using the wheels. Then, the engine can be fired.

For AR202 equipped models without wheels, rotation can be induced by steering the rocket (actuating the gimbals on the Terrier engine) and pulsing the engine once. Once the engine is about to pass the retrograde orientation, it can be fired to deorbit the rocket.

Troubleshooting

Stability issues for second stage

Problem

When the first stage is discarded, the rocket immediately tumbles out of control. Rocket takes a retrograde attitude, or points randomly.

Root cause

The centre of mass of the upper stage and payload bay is too low. The payload mass is below the minimum allowable mass, or the payload has an unusually low centre of mass. This does not affect the first stage since it has fins. Discarding the fins causes the centre of pressure to move close to the centre of mass.

Solution

During mission planning, ensure the centre of mass if always above the centre of pressure. This can be verified by activating both overlays, re-rooting the rocket as to make the payload its root and temporarily disconnecting the lower stage. Consider an allowance for centre of gravity rise as the fuel tank is drained.

If loss of control of this type is predicted before lower stage release, keep the lower stage for as long as possible, even after lower stage sustainer shut down. With the lower stage attached, its fins should be able to keep the rocket in a prograde attitude. If there is fuel in the stage, attempt to change the ascent angle to force a steep climb. At 34 Km altitude, the aerodynamic forces should be small enough not to impact on the upper stage's trajectory.

If this type of loss of control happens during a mission, the emergency procedure indicated below can be attempted. This scenario is rarely survivable unless full-size parachutes are available for deployment. For crewed capsules, this procedure results in an ejection and abort into the ocean.

1. Cut thrust as soon as control is lost. Do not waste propellant trying to regain control the upper stage.
2. Coast to apoapsis, which should be at an altitude of approximately 20 to 30 kilometers.
3. At apoapsis, assume a retrograde attitude by whatever means available, including reaction wheels and the gimbaled thrust of the upper stage rocket.
4. As soon as a retrograde (or near retrograde) attitude is achieved, eject the payload fairing. Do not wait unnecessarily, as the orientation may be hard to maintain.
5. As soon as the fairing is ejected, the rocket should naturally establish a retrograde attitude.
6. For crewed capsules and payloads with means of recovery, eject them and follow their abort procedures.
7. For payloads without recovery modes, continue following this list to attempt a powered descent into the ocean. This procedure is rarely survivable, usually splashing at 20 to 35 m/s into the ocean.
8. Use the Terrier engine to reduce horizontal speed to near 0, relative to surface, reducing upper stage mass at the same time.
9. Deploy parachutes, if available. If parachutes will reduce vertical speed to below 50 m/s at 1000 metres altitude, skip to step 11.
10. Descend until 6300 metres altitude is reached, and then apply full thrust downwards. If parachutes are available, apply partial thrust, letting the parachute do most of the decelerating.
11. As 50 m/s speed is reached (at approximately 1000 metres altitude), maintain this speed until 750 metres altitude is reached.
12. Apply thrust as necessary to reduce vertical speed to less than 7 m/s. Without parachutes, full thrust is needed. Beware, as Terrier engine becomes ineffective close to sea level.
13. Hold a 7 m/s speed until splashdown. Cut thrust immediately at touchdown.

Loss of power during ascent

Problem

During a shallow ascent, control is lost as the rocket runs of electric charge before establishing a stable orbit.

Root causes

The ascent angle is too shallow and orbital procedures take too long. Operation of the computer and reaction wheels for such a long period drain the rocket's battery. This may happen on shallow ascents with inert payloads that have no onboard batteries or other electric charge sources.

Another possibility is the presence of an active, high power payload draining the rocket's batteries.

Solution

High power payload loads should not be enabled until after orbital procedures are complete. Ensure payloads are shut down during launch.

During mission planning, if a shallow ascent trajectory is required, ensure that enough power will be available by at least one of these means.

- Install additional batteries in the rocket's avionics bay.
- Use the payload's batteries as an extra electric charge source.
- Use a P or Q type power system. This system has a solar panel in the rocket's west (dorsal) position, enabling it to keep the battery charged. Launching east shortly before sunrise improves the chance of successful payload deployment.
- Execute a roll at launch to position one of the solar panels pointing towards the sun. Alter the force roll option in MechJeb or execute the roll during SAS or manual ascents.

A loss of power is not survivable during atmospheric flight. The only mitigation is detection of the low power situation before the rocket shuts down.

If a loss of electrical power is predicted in atmospheric flight, execute a roll maneuver to point a solar panel towards the sun. To improve survivability, manually manage the computer and reaction wheels, setting the computer to hibernation mode during coasting. Do not maneuver unnecessarily, as this increases power usage. Prioritize reaching orbit (even a lower unintended one).

If loss of power is predicted in orbit (even unstable ones), immediately assume a sun-seeking attitude, orienting one solar panel to the sun. This should be done even on the night side, as even if power is lost, control can be regained after the rocket passes the planet's shadow. If proper orientation is not known or not achievable before power loss, induce a roll, to maximize the chances that one solar panel will be exposed to the sun at least during part of a revolution. Once some power is regained, immediately assume a sun seeking attitude. All power management techniques explained for atmospheric flight should be applied to orbital flight as well.

Fuel exhaustion

Problem

Fuel is exhausted before a stable orbit is achieved.

Root cause

Fuel exhaustion usually occurs due to either staging errors, inefficient ascent profiles or overloaded rockets.

Solution

Payloads should conform to the limits indicated in this manual. Never exceed maximum payload masses, as the carrier rocket will fail to reach orbit, even if this is not obvious at launch. As payloads reach the maximum mass, the window between steep and shallow launches becomes smaller, requiring precise orbital insertion. If the payload exceeds this mass, the window will be reduced to zero, never successfully achieving orbital insertion, despite successful takeoffs.

If enough precision for orbital insertion cannot be achieved, switch to a more powerful version of the rocket or reduce payload mass. As mass margins increase, so does the insertion window. Launching with a mass below the maximum allowed also enables less precise launches.

Unstable orbits

Problem

An orbit is achieved, but there is a large difference between periapsis and apoapsis, with its periapsis possibly below the Kerman line.

Root cause

Unstable orbits are mainly caused in MechJeb ascents due to a steep climb. Using the parameters indicated may lead to an unstable orbit if the trajectory is too steep, because the circularization burn takes place past apoapsis, and is stopped at an average desired altitude, with high eccentricity.

In properly executed manual circularization burns, this should not happen, unless an error is introduced in the procedure.

Solution

If a steep climb is executed, consider doing a manual circularization. This may still end up with an elliptic orbit if the ascent is too steep, but should be more controllable.

Most burns leading to unstable orbits happen past apoapsis, so the rocket will reenter the atmosphere before reaching apoapsis. If this is NOT the case, wait until apoapsis and execute a new circularization burn.

If an unstable orbit was achieved, it may be possible to do a prograde burn to attempt to raise the periapsis above 70 Km. This may raise apoapsis further, but will prevent atmospheric reentry. The orbit may later be corrected at periapsis.

If a prograde burn will not correct the situation (usually because the craft’s altitude is close to the Kerman line and dropping), an anti-radial (radial out) burn may move the periapsis out of the atmosphere, giving time to correct the situation. This boils down to using the rocket engine to directly fight gravity, hovering while orbiting. This is not efficient, but may work if there are enough fuel reserves.

Another possibility is to coast through the atmosphere. If the payload fairing was not ejected, ejection should wait until after the atmospheric coast is complete. A prograde attitude should be taken and the rocket engine should be use to counteract drag. Once the atmospheric coast phase is passed, the orbit can be corrected as the rocket passes through apoapsis. This procedure should be executed only if the periapsis passes above 60 kilometres and if the payload can take the stress. Drag increases drastically for every kilometer below the Kerman line, and any technique available should be used to increase periapsis altitude. A difference of a couple of kilometres in periapsis altitude can severely impact drag and thermal properties of the coast.

Test data

The table below shows the parameters fed to Mechjeb2 for running the tests.

		R-3-1200	2L30-400
TARGET	Orbit altitude (Km)	80	80
	Inclination (deg)	0	0
GUIDANCE	Turn start altitude (Km)	0.5	0.5
	Turn start velocity (m/s)	50	35
	Turn start pitch	see table below	see table below
	Int. altitude (Km)	80	80
	Hold AP time (s)	1	1
OPTIONS	Prev. engine ovrheat	No	No
	Limit Q	No	No
	Limit Acceleration	No	No
	Keep limited throttle	No	No
	Electric limit	No	No
	Force roll climb		No
	Limit AOA (deg)	5	10
	Dynamic pres FO (Pa)		2500
	Autostage		Yes
	Autostage delay, pre (s)		0.5
	Autostage delay, post (s)		1
	Clamp autostage thr (%)		0.99
	Stg frings, dyn prs (KPa)		5
	Stg frings, altitude (Km)		50
	Stg frings, flux (W/m^2)		1135
	Stop at stage[6]	1 for single 2 for dual	1 for single 2 for dual
	Auto deploy solar panels	No	No

6 Assumes single payload with no additional staging in each bay. Fully read this section and adjust properly if that is not the case.

Test data for R-3-1200

All ascent calculations executed on a S1-H1X-1O series rocket with inert payload and corrected to effective payload using the type assembly mass correction procedure.

R-3-1200 MJ2 gravity turn angle table for 500 Kg payload								
pitch	result	dV remaining	T to orbit	AP error	PE error	Circ burn (m/s)	Circ burn (s)	Notes
2	No orbit, burn fails to raise PE over Kerman (AKA Kármán) line.							
5	Too steep	1389	4:02	899	-1294	1742	82	
10	Too steep	1571	4:10	6500	-6500	1364	60	
15	OK	1617	4:17	4116	-204	1110	47	
16	OK	1621	4:14	3737	-3929	1064	45	
17	OK	1624	4:17	3399	-3504	1019	43	
18	OK	1626	4:18	3067	-3270	973	41	
19	OK	1628	4:21	2773	-2892	930	39	
20	OK	1629	4:25	2500	-2650	887.2	37	
21	OK	1629	4:26	2243	-2466	844	35	
22	OK	1628	4:28	2005	-2130	803	33	
23	OK	1627	4:31	1782	-1946	762	31	
24	OK	1626	4:35	1592	-1738	723	29	
25	OK	1624	4:38	1410	-1541	684	27	
26	OK	1622	4:43	1243	-1460	644	26	
27	OK	1620	4:47	1065	-1241	612	24	
28	OK	1617	4:52	960	-1094	576	23	
29	OK	1614	4:57	835	-984	541	29	
30	Too shallow	1611	5:02	732	-872	510	20	
40	Too shallow	1570	6:25	126	-178	245	9	
50	Too shallow	1488	9:55	-2	-161	91	3	
52	No orbit, AP too far away and rocket runs out of electrical power. Non negligible chance of power system damage.							
60	No orbit, AP too far away and rocket runs out of electrical power. Non negligible chance of power system damage.							

R-3-1200 MJ2 gravity turn angle table for 1000 Kg payload

pitch	result	dV remaining	T to orbit	AP error	PE error	Circ burn (m/s)	Circ burn (s)	Notes
10	Unstable orbit	885	4:20	10458	-10273	1208	58	PE below Kerman line
11	Too steep	898	4:21	9148	-9046	1134	54	
12	Too steep	907	4:25	8002	-7946	1062	50	
14	OK	921	4:30	5938	-3070	920	43	
15	OK	924	4:36	5056	-5124	851	39	
16	OK	927	4:40	4289	-4373	786	36	
17	OK	928	4:43	3582	-3676	720	32	
18	OK	928	4:49	2965	-3088	657	29	
20	OK	926	5:03	1973	-2100	540	23	
22	OK	922	5:21	1254	-1384	433	18	
23	OK	919	5:32	984	-1128	387	23	
25	Too shallow	913	5:59	590	-222	303	12	
30	Too shallow	896	7:42	135	-292	160	6	
35	Too shallow	868	10:17	1469	-1683	87	3	
37	Unstable orbit, rocket runs out of electrical power during circularization burn and gets lofted into elliptical orbit.							
40	No orbit, AP too far away and rocket runs out of electrical power.							

R-3-1200 MJ2 gravity turn angle table for 1500 Kg payload								
pitch	result	dV remaining	T to orbit	AP error	PE error	Circ burn (m/s)	Circ burn (s)	Notes
9	Unstable orbit	394	4:32	11833	-17346	1042	53	PE below Kerman line
10	Too steep	423	4:54	5010	-5068	682	33	
12	Too steep	423	4:53	5035	-5100	683	33	
13	OK	427	5:50	3462	-4568	568	27	
15	OK	429	5:38	1530	-1739	379	17	
16	OK	429	6:03	916	-1066	298	13	
17	OK	428	6:33	563	-688	233	10	
18	OK	427	7:10	313	-460	182	8	

19	OK	426	7:55	171	-327	143	6	
20	Too shallow	423	8:42	93	-246	112	5	
22	Too shallow	413	10:51	22	-172	73	3	
23	No orbit, AP too far away and rocket runs out of electrical power.							

R-3-1200 MJ2 gravity turn angle table for 2000 Kg payload								
pitch	result	dV remaining	T to orbit	AP error	PE error	Circ burn (m/s)	Circ burn (s)	Notes
7	Fuel exhaustion, no fuel on a 90x58 km unstable orbit.							
8	Too steep	17	5:04	8439	-8370	757	40	
9	Too steep	29	5:18	4095	-4179	528	27	
10	Too steep	37	5:50	1709	-1822	343	17	
11	Too steep	42	6:50	598	-733	207	10	
12	Too steep	48	8:13	123	-327	166	6	
13	OK	52	10:07	66	-235	77	3	
14	No orbit, AP too far away and rocket runs out of electrical power.							

Test data for R-3-1200-2L30-400

R-3-1200-2L30-400 tests were executed on a R-3-1200-2L30-400-S1-H1X-1O rocket and corrected using the indicated procedure.

R-3-1200-2L30-400 MJ2 gravity turn angle table for 2000 Kg payload								
pitch	result	dV remaining	T to orbit	AP error	PE error	Circ burn (m/s)	Circ burn (s)	Notes
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								

39								
40								

R-3-1200-2L30-400 MJ2 gravity turn angle table for 2500 Kg payload								
pitch	result	dV remaining	T to orbit	AP error	PE error	Circ burn (m/s)	Circ burn (s)	Notes
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								

39								
40								

R-3-1200-2L30-400 MJ2 gravity turn angle table for 3000 Kg payload								
pitch	result	dV remaining	T to orbit	AP error	PE error	Circ burn (m/s)	Circ burn (s)	Notes
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
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29								
30								
31								
32								
33								
34								
35								
36								
37								
38								

39								
40								

R-3-1200-2L30-400 MJ2 gravity turn angle table for 3400 Kg payload								
pitch	result	dV remaining	T to orbit	AP error	PE error	Circ burn (m/s)	Circ burn (s)	Notes
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
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40								

Test data for R-3-1200-2L30-400, 60% fins

R-3-1200-2L30-400 tests were executed on a prototype R-3-1200-2L30-400-S1-H1X-1O rocket and corrected using the indicated procedure. The prototype had 60% fin deflection instead of the final 40%.

R-3-1200-2L30-400 MJ2 gravity turn angle table for 2000 Kg payload								
pitch	result	dV remaining	T to orbit	AP error	PE error	Circ burn (m/s)	Circ burn (s)	Notes
9		456	4:12	19316	-18442			PE below Kerman line
10								
11		511	4:07	10610	10490			PE below Kerman line, correctable
12		541	4:05	6662	-6741	1625		1st stage circ burn
13								
14		588	4:02	2331	-2684	1527		
15								
16								
17								
18								
19								
20								
21								
22								
23								
24		708	4:07	100	-246			1st stage circ burn
25								
26								
27		728	4:14	1294	-1439	956	65	
28		730	4:16	76	-209	900	61	
29								
30		729	4:24	667	-808			

31		727	4:29	499	-628	705	46	
32		723	4:36	338	-479	631	41	
33								
34								
35								
36								
37								
38		665	6:54	9	-156	181	10	
39								
40		628	9:43	-11	-166	92	5	
41	No orbit, power loss on shallow trajectory							
42	No orbit, power loss on shallow trajectory							

R-3-1200-2L30-400 MJ2 gravity turn angle table for 2500 Kg payload								
pitch	result	dV remaining	T to orbit	AP error	PE error	Circ burn (m/s)	Circ burn (s)	Notes
12								
13								
14	Too steep	301	4:13	9209	-9128			1st stage circ burn
15								
16								
17								
18	Too steep	366	4:09	506	-666			1st stage circ burn
19								
20								
21								
22		409	4:13	2391	-2501	1137	85	
23								
24								
25	Too steep	427	4:17	1539	-1669	983	72	
26	OK	431	4:19	1259	-1376	921	67	
27	OK	433	4:22	990	-1114	855	62	
28	OK	435	4:27	765	-885	783	56	
29	OK	435	4:32	535	-674	706	50	

30	OK	433	4:40	356	-487	622	43	
31	OK	429	4:51	208	-339	534	37	
32	Too shallow	425	5:05	105	-234	445	30	
33	Too shallow	419	5:26	48	-169	354	24	
34	Too shallow	411	5:56	17	-147	274	18	
35	Too shallow	402	6:38	13	-149	198	12	
36	Too shallow	393		2	-131	142	9	
37	Too shallow	382	8:54	-1	-150	99	6	
38	No orbit, power loss on shallow trajectory							
39	No orbit, power loss on shallow trajectory							
40								
41								
42	No orbit, rocket reaches thermal limits and burns in lower atmosphere							
43								
44								
45								
46								

R-3-1200-2L30-400 MJ2 gravity turn angle table for 3000 Kg payload								
pitch	result	dV remaining	T to orbit	AP error	PE error	Circ burn (m/s)	Circ burn (s)	Notes
29	Too steep	189	4:49	12772	-12444	743	56	PE below Kerman line
30	Too steep	190	4:55	10216	-10060	665	50	PE below Kerman line, correctable
31	OK	190	5:00	7974	-7918	588	43	
32	OK	189	5:08	5940	-5969	508	37	
33	Too shallow	186	5:19	4169	-4264	426	31	
35	Too shallow	179	6:00	1718	-1852	275	19	
40	Too shallow	157	10:28	74	-233	69	4	

R-3-1200-2L30-400 MJ2 gravity turn angle table for 3300 Kg payload								
pitch	result	dV remaining	T to orbit	AP error	PE error	Circ burn (m/s)	Circ burn (s)	Notes
17	Too steep	0	4:18	2913	-7603	1260	103	Fuel exhaustion during circ burn
18	Too steep	8	4:20	3172	-3635	1216	102	
19	Too steep	18	4:21	2852	-3136	1166	97	
20	Too steep	28	4:21	2481	-2645	1108	92	
21	Too steep	36	4:26	2142	-2264	1053	86	
22	Too steep	43	4:24	1775	-1916	933	81	
23	Too steep	50	4:29	1376	-1514	916	74	
24	Too steep	55	4:32	1020	-1139	830	66	
25	Too steep	59	4:40	687	-827	735	58	
26	OK	61	4:44	419	-538	631	49	
27	OK	61	4:57	221	-333	519	39	
28	OK	61	5:16	83	-224	405	30	
29	Too shallow	59	5:43	27	-165	298	22	
30	Too shallow	56	6:30	7	-130	205	14	
31	Too shallow	52	7:36	7	-145	131	9	
32	Too shallow	48	9:19	7	-157	82	5	
33	Too shallow	44	11:16	26	-174	58	4	
34	Too shallow	37	14:34	1186	-1290	43	2	May run out of EC

R-3-1200-2L30-400 MJ2 gravity turn angle table for 3400 Kg payload

pitch	result	dV remaining	T to orbit	AP error	PE error	Circ burn (m/s)	Circ burn (s)	Notes
22	Too steep	3	4:26	1614	-1734	956	78	
23	Too steep	11	4:29	1217	-1338	876	71	
24	Too steep	16	4:33	843	-980	782	63	
25	Too steep	19	4:40	543	-665	680	54	
26	OK	21	4:50	295	-422	567	44	
27	OK	21	5:07	127	-271	445	34	
28	Too shallow	20	5:32	42	-164	331	25	
29	Too shallow	18	6:10	13	-155	231	17	
30	Too shallow	16	7:08	1	-151	153	11	
31	Too shallow	14	8:35	22	-151	97	7	
32	Too shallow	10	10:38	21	-184	63	4	
33	No orbit, power loss on shallow trajectory							

R-3-1200-2L30-400 MJ2 gravity turn angle table for 3500 Kg payload								
pitch	result	dV remaining	T to orbit	AP error	PE error	Circ burn (m/s)	Circ burn (s)	Notes
26	No orbit, fuel exhaution during circularization burn							
27	No orbit, fuel exhaution during circularization burn							
30	No orbit, fuel exhaution during circularization burn							
31	No orbit, fuel exhaution during circularization burn							
32	No orbit, fuel exhaution during circularization burn							
33	No orbit, fuel exhaustion on shallow trajectory							