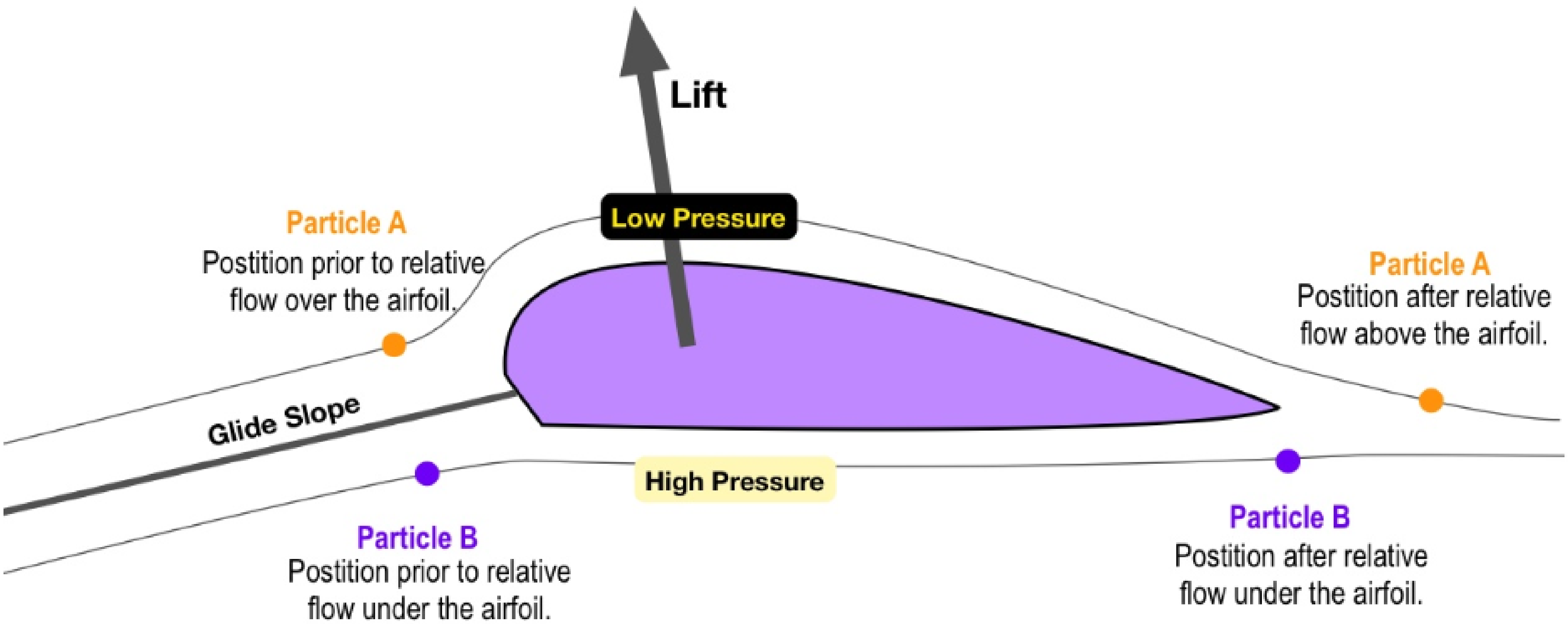
HOW DOES AN AIRPLANE FLY?

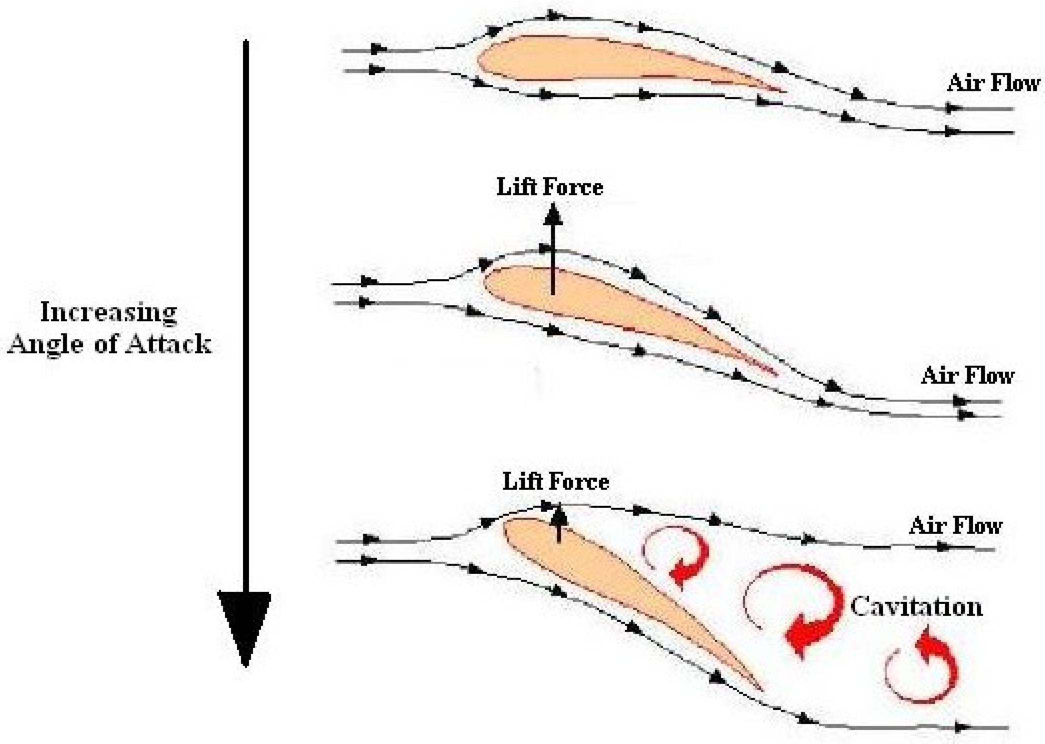
Air Moves Faster Over Top of Wing

Below particle "A" moves faster than particle "B" and travels not only the increased distance over the top surface (moving over the curved top surface is a much further distance), but moves so much faster than particle B that it arrives well past the trailing edge at the same time that particle B reaches the trailing edge.

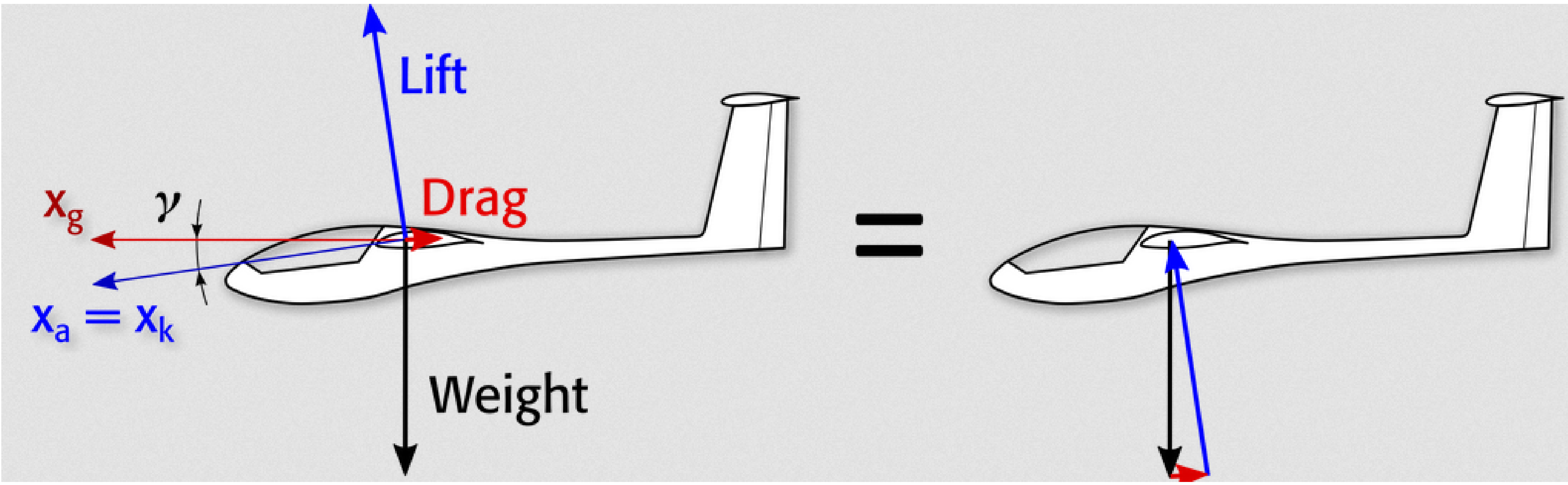


STALL – the plan stops flying!

- If you slow down, to keep the same lift you increase the angle of attack.
- But only to a certain point.



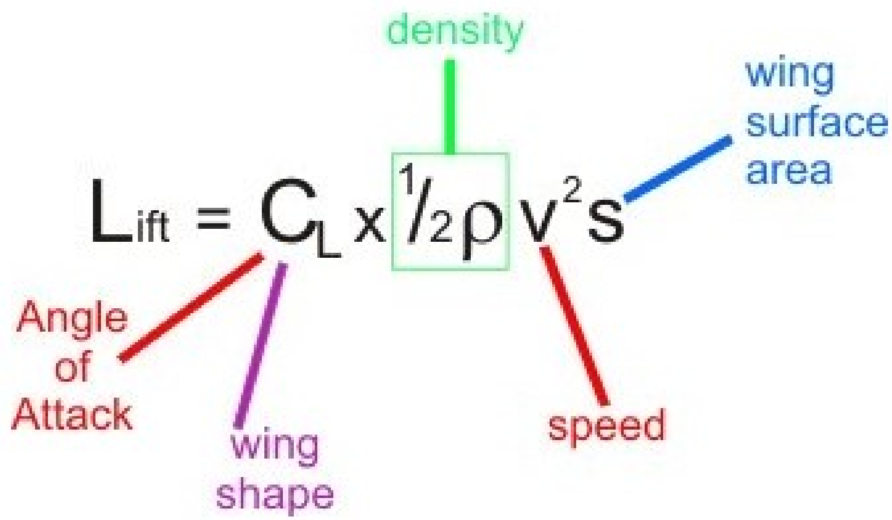
HOW DOES A GLIDER FLY?

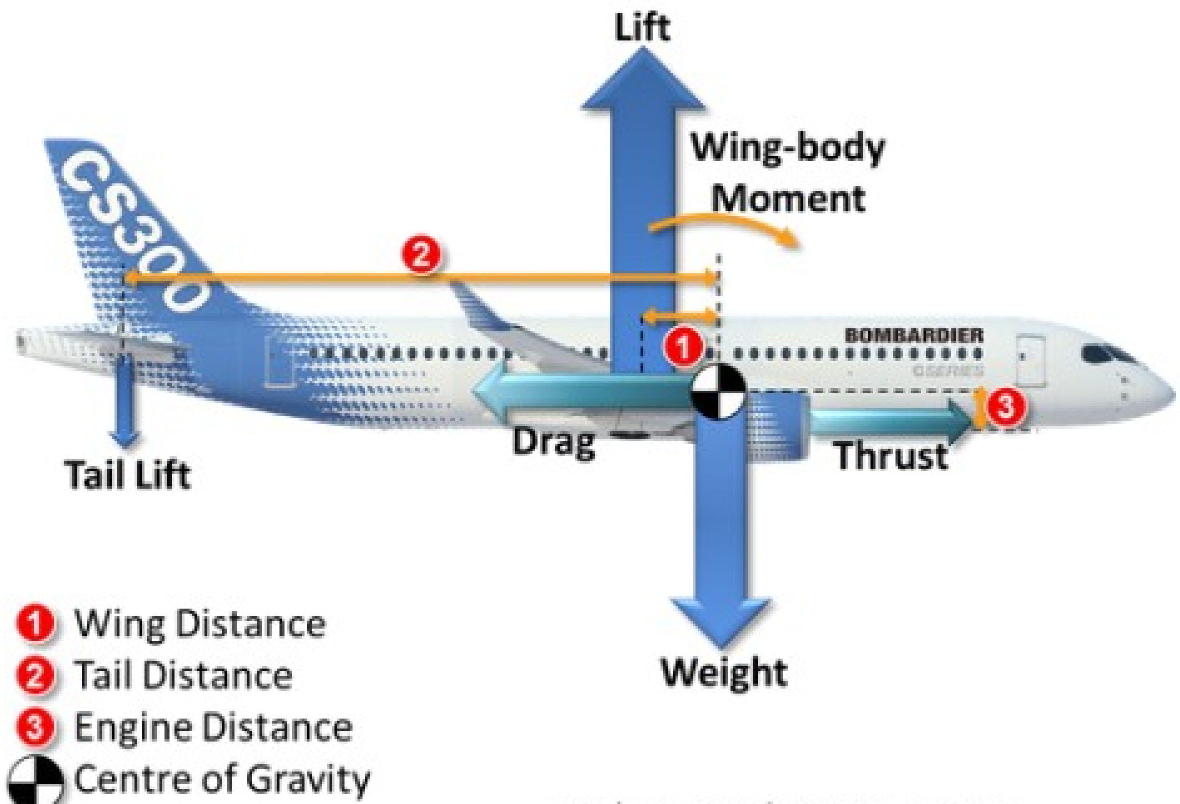


The flight path angle *γ* is negative and in still air the flight path vector x*k* is parallel to the direction of the airspeed. Due to the inclination of the flight path, the lift vector is tilted forward such that its horizontal component is exactly opposite to the drag force. This is shown on the right where I moved the vectors into a closed sequence which demonstrates that all forces balance.

From the viewpoint of the glider, the lift is pointing straight up and drag directly backwards, but the weight force is slightly tilted forward. The thrust of a glider is its weight force.

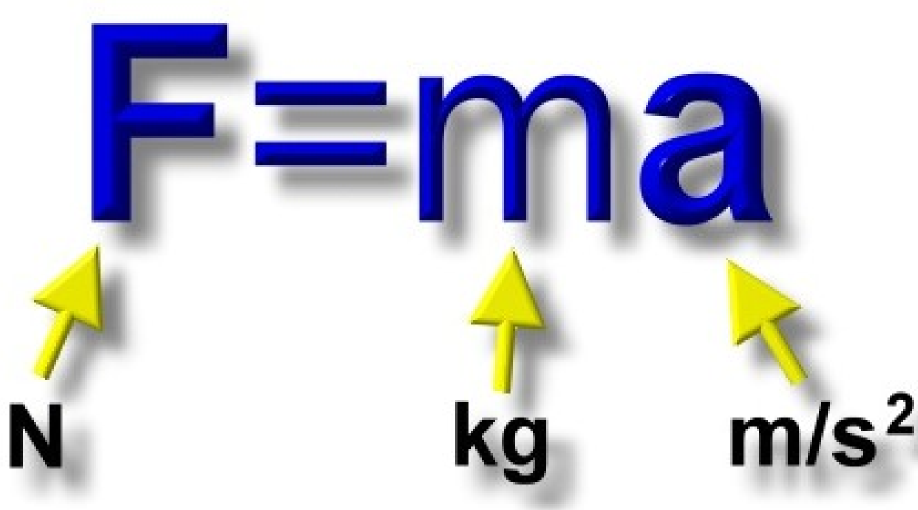
Now let the whole air packet in which the glider flies move up. The glider will still sink down within this air but relative to the ground it will gain altitude if the upward air velocity is high enough.





Airplane Pitching Moments

HOW DOES A ROCKET FLY?



Newton's SECOND equation of motion.

A **Newton** is the amount of force necessary to accelerate a **Mass** of one **Kilogram** at rate of one **Meter** per second squared.

– converted to English units –

A **Pound** is the amount of Force necessary to accelerate a **Mass** of one **Slug** at rate of one **Foot** per second squared.

What's Mass? – A value that reflects the amount of matter present**.**

What's a Slug? – At the surface of the Earth, divide weight in pounds by 32.2, also 1 G, also how fast a dropped body accelerates on the surface of the earth, 32.2 ft/second^2

Your **Weight** depends on gravity. Your **Mass** never changes *(unless you go on a diet!)*.

Velocity = Acceleration * time

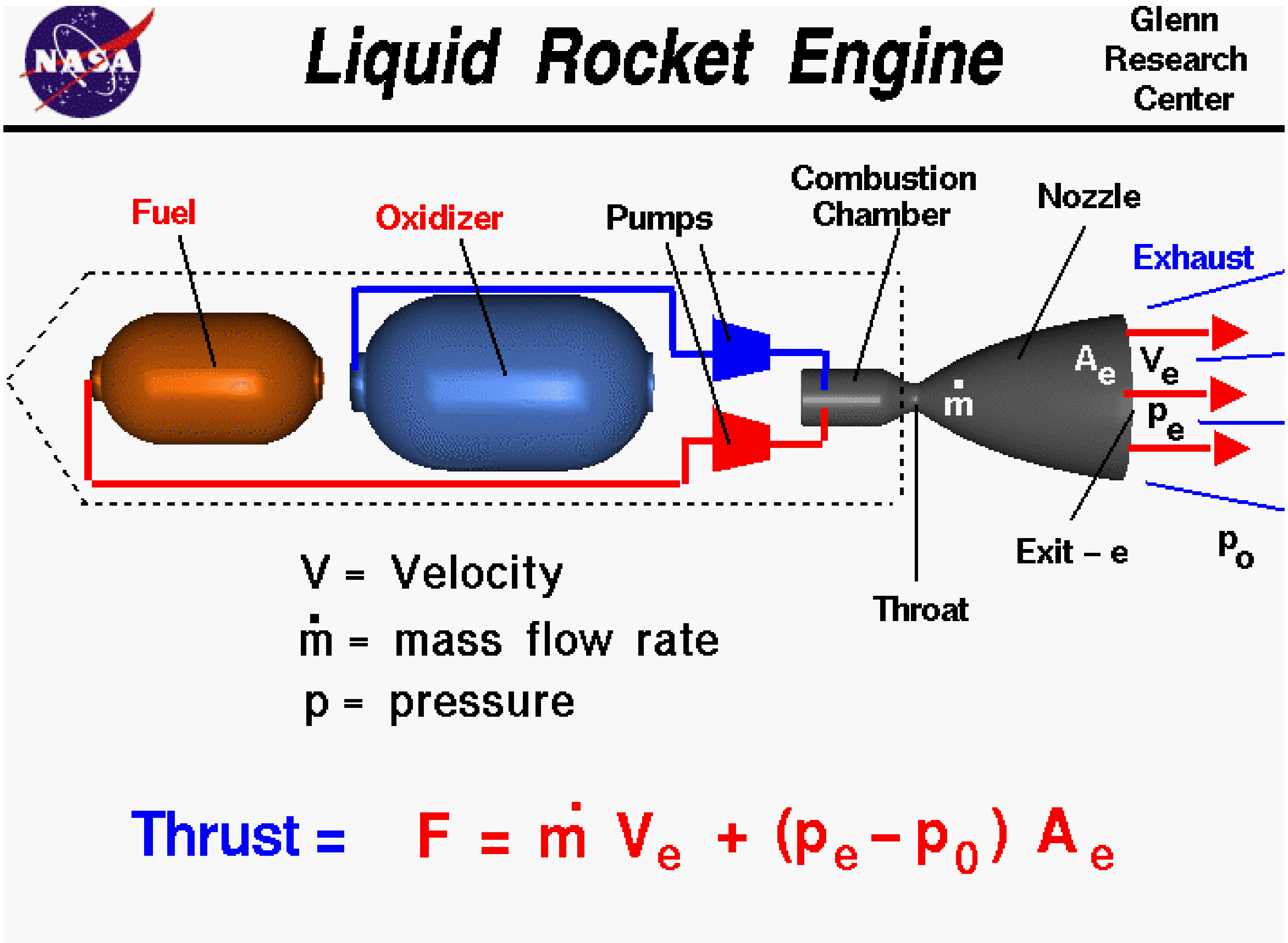
Velocity needed to orbit the Earth – 18,000 Miles/Hour OR 26,000 feet/second

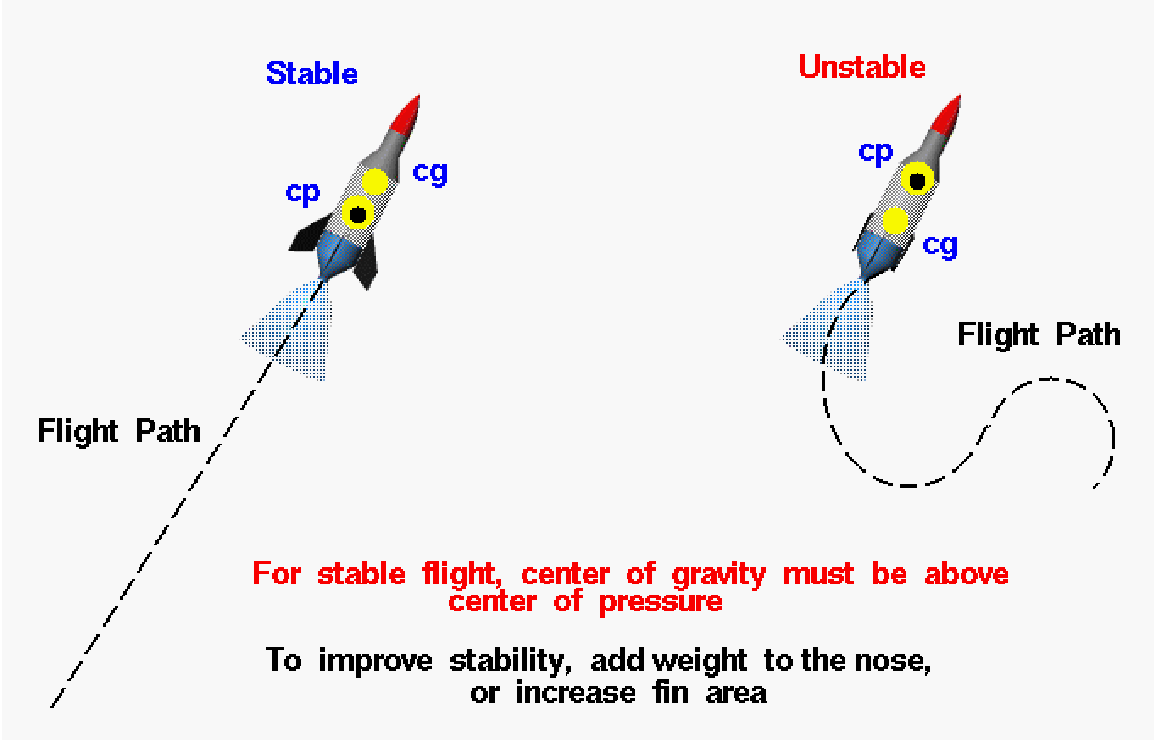
IF a rocket carrying an Astronaut accelerated at a constant 3 G's, how long to reach orbital velocity?

26,000 = (3 * 32.2) * time OR (using algebra) time = 26,000 / (3 * 32.2) OR time = 26,000 / 96.6
OR **time = 269 seconds (about 4.5 minutes)**

TYPES OF ROCKET ENGINES

They all need FUEL & OXIDIZER to keep the fire burning. These can be stored separately as liquids, or bound together in a solid form. Sometimes a combination of both is used.

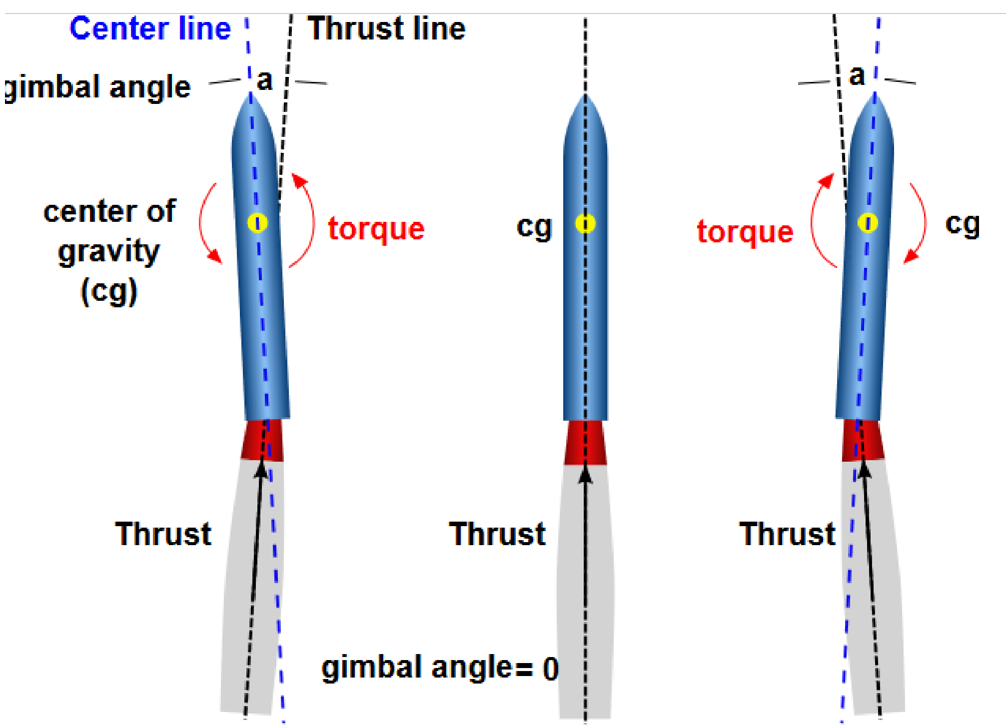




STABILITY

Older rockets like the V-2 and model rockets use fins.

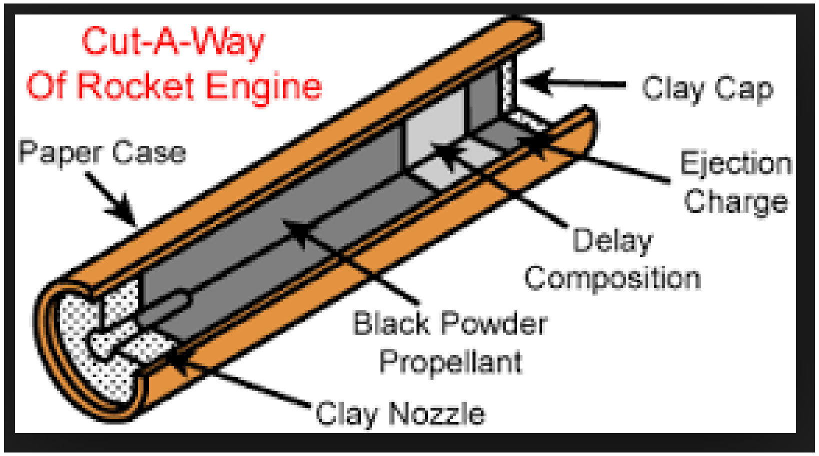
They needed to be far back and quite large (and HEAVY!).



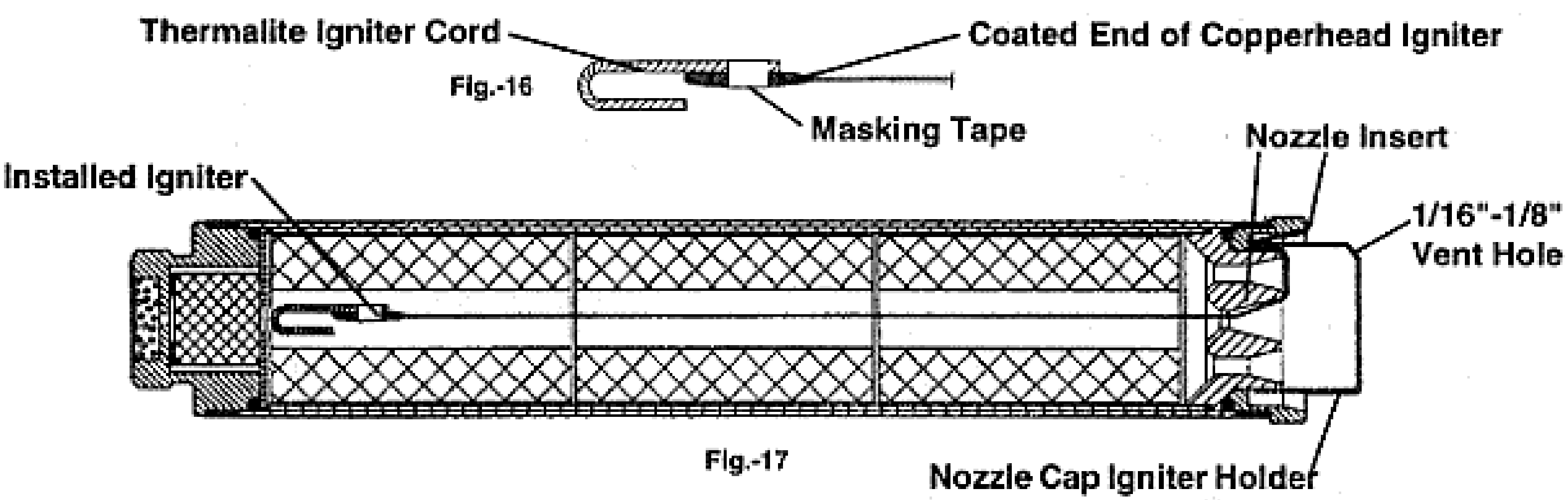
The large rockets we see on TV no longer have fins. The engines are mounted on gimbals/bearings and are moved during flight .

Controlled VERY CAREFULLY by a computer program.
The guidance system.

Model rocket engines are rated from a baseline denoted as "A". Each successive letter is double the last letter's impulse, so an F engine is 2x the impulse of a E, and 32x that of an A. The letter is followed by a number which gives average thrust, in Newtons. A permit is required to fly anything larger than G size. Delay is denoted by a number after a dash. After the delay, a charge bursts through the top of the engine to deploy the parachute or other recovery system.



Internals of A-E engines.



F- G engines

```
#!/usr/bin/perl
# Simple rocket simulation, fixed thrust, english units.
# Mass in slugs, force in pounds, acceleration/velocity in
# feet/second.

# external constants
my $AIR_DENSITY = .002378;   # slugs/cubic foot at sea level
my $POUNDS_TO_SLUGS = 32.2;  # convert pounds to slugs
my $STOP_TIME = 8.00;        # number of seconds to simulate
my $TIME_INCREMENT = .25;

# rocket constants
my $BURNOUT_TIME = 1.75; # engine burnout in seconds
my $COEFF_DRAG = .1;     # coefficient of drag for the rocket
my $HEIGHT_INCH = 24;    # Body height/diameter
my $DIAMETER_INCH = 2;
my $FIN_AREA_SQ_IN = 48;
my $THRUST_NEWTONS = 12; # Engine thrust
my $WEIGHT_OZ = 9.5;

# do some conversions for the proper units
my $weight = $WEIGHT_OZ / 16;   # weightin pounds
my $mass = $weight / $POUNDS_TO_SLUGS;
my $thrust = $THRUST_NEWTONS * .2248;   # thrust in pounds
my $area = $FIN_AREA_SQ_IN + 3.1415 * $DIAMETER_INCH * $HEIGHT_INCH; #
square inches
$area = $area/144; # square feet
```

```
# INITIALIZE VARIABLES TO ZERO
my $acceleration = 0;  my $curTime = 0;      my $curSpeed = 0;
my $curSpeedKts = 0;   my $curDistance = 0; my $distance = 0;
my $drag = 0;          my $force = 0;       my $speed = 0;

# print some headings
print ("Rocket weight is $weight pounds, thrust is $thrust pounds,
area is $area square feet.\n");
print ("Time(seconds)\tThrust/Force\tAccel(ft/sec2)\tSpeed(Ft/Sec Kts)
Altitude(feet)\tDrag(pounds)\n");


while ($curTime < $STOP_TIME)   {

  # how much drag on the rocket
  $drag = .5 * $AIR_DENSITY * $COEFF_DRAG * $area * $curSpeed *
$curSpeed;

  # acceleration of rocket - Newtons equation of motion
  # F (Force in pounds) = M (Mass in slugs) * A (Acceleration in
ft/sec/sec)
  # A = F/M
  if ($curTime > $BURNOUT_TIME) {
    $thrust = 0;
  }

  # count drag as a negative force if we are moving up.
  # With negative speed, descending, drag slows us down.
```

```
  if ($curSpeed < 0) {
        $drag = -$drag;
  }
  $force = $thrust - $drag - $weight;
  $acceleration = $force / $mass;

  # print the information
  printf("%5.2f\t\t%5.2f/%5.2f\t\t%5.2f\t\t%d %d\t\t%5.2f\t\t%5.2f\n",
          $curTime, $thrust, $force, $acceleration, $curSpeed,
$curSpeedKts, $curDistance, $drag);


  # calculate the distance
  # distance = 1/2 * A * T squared + (velocity * time)
  $distance = .5 * $acceleration * $TIME_INCREMENT**2 +
                    ($curSpeed * $TIME_INCREMENT);

  # add the numbers for this second to the earlier numbers
  $curDistance = $curDistance + $distance;
  $speed = $acceleration * $TIME_INCREMENT;
  $curSpeed = $curSpeed + $speed;

  # covert the curSpeed to knots (6000 ft/nautical mile)
  # there are 3600 seconds in an hour.
  $curSpeedKts = $curSpeed * 3600 / 6000;

  $curTime = $curTime + $TIME_INCREMENT;  # update the time
}
```

Rocket weight is 0.59375 pounds, thrust is 2.6976 pounds, area is 1.3805 square feet.

Time(secs)	Thrust/Force	Accel(ft/sec2)	Speed(Ft/Sec Kts)	Altitude(feet)	Drag(pounds)
0.00	2.70/ 2.10	114.10	0 0	0.00	0.00
0.25	2.70/ 1.97	106.85	28 17	3.57	0.13
0.50	2.70/ 1.60	86.94	55 33	14.04	0.50
0.75	2.70/ 1.13	61.36	76 46	30.56	0.97
1.00	2.70/ 0.71	38.24	92 55	51.72	1.40
1.25	2.70/ 0.40	21.72	101 61	75.99	1.70
1.50	2.70/ 0.21	11.61	107 64	102.14	1.89
1.75	2.70/ 0.11	5.99	110 66	129.33	1.99
Engine burnout, but notice how total upward force declined, DRAG became very LARGE					
2.00	0.00/-2.64	-143.26	111 67	157.07	2.05
2.25	0.00/-1.54	-83.46	75 45	180.51	0.95
2.50	0.00/-1.09	-59.15	55 33	196.88	0.50
2.75	0.00/-0.86	-46.61	40 24	208.78	0.27
3.00	0.00/-0.73	-39.47	28 17	217.38	0.13
3.25	0.00/-0.65	-35.32	18 11	223.30	0.06
3.50	0.00/-0.61	-33.07	9 5	226.87	0.02
3.75	0.00/-0.59	-32.22	1 0	228.31	0.00
4.00	0.00/-0.59	-31.83	-6 -3	227.70	-0.01
4.25	0.00/-0.56	-30.35	-14 -8	225.10	-0.03
4.50	0.00/-0.51	-27.90	-21 -13	220.55	-0.08
4.75	0.00/-0.46	-24.73	-28 -17	214.18	-0.14
5.00	0.00/-0.39	-21.21	-35 -21	206.17	-0.20
5.25	0.00/-0.33	-17.64	-40 -24	196.72	-0.27
5.50	0.00/-0.26	-14.29	-44 -26	186.06	-0.33
5.75	0.00/-0.21	-11.32	-48 -29	174.40	-0.38
6.00	0.00/-0.16	-8.81	-51 -30	161.94	-0.43
6.25	0.00/-0.12	-6.76	-53 -32	148.85	-0.47
6.50	0.00/-0.09	-5.12	-55 -33	135.27	-0.50
6.75	0.00/-0.07	-3.85	-56 -33	121.32	-0.52