DEGREE of SATURATION

Best Measure

- The best measure of traffic density is Degree of Saturation
- Volume alone is misleading as it takes no account of road capacity.
- Another term for Degree of Saturation is traffic density
- Degree of Saturation is usually expressed in percent (%) whereas traffic density tends to be referred to as vehicles per lane per kilometre which takes no account of capacity.

In the most simplistic terms, the Degree of Saturation of a section of road can be expressed as follows:

$$x = q / Q$$

where x - Degree of Saturation]

- q - actual flow rate (in any appropriate units) (usually vehicles per hour)
- Q - maximum achievable flow

Flow at Signals

Each lane of a road has a fairly constant maximum flow capability, i.e. there is a relatively predicable "saturation flow" level at which maximum throughput occurs. At traffic signals, this saturation flow can obviously only occur while the signal facing the particular approach is green.

The fraction of the time that vehicles can flow is given by the ratio [g/C]

- where g = green time for an approach
- C = cycle length

Flow at Signals

Therefore the capacity Q of an approach is:

$$Q = sg/C$$

Substituting this equation for Q above gives a DS at traffic signals:

$$x = qC/sg$$

DS

In SCATS we refer to 'x' as 'DS' - Degree of Saturation.

So

$$DS = qC/sg$$

s = Saturation flow

Some Fundamentals:

All other variables being the same -

- DS will increase if q (demand) increases
- DS will increase if C (cycle length) increases
- DS will increase if s (saturation flow) decreases
- DS will increase if g (green time) decreases
- DS will increase if the g/C ratio (split) decreases

Some Fundamentals:

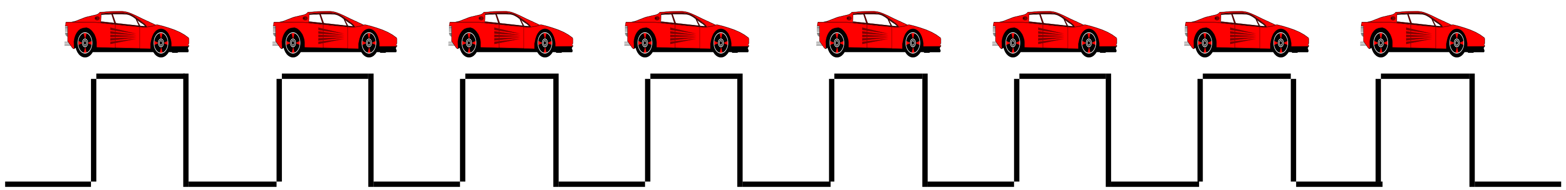
- DS will decrease if q (demand) decreases
- DS will decrease if C (cycle length) decreases
- DS will decrease if s (saturation flow) increases
- DS will decrease if g (green time) increases
- DS will decrease if the g/C ratio (split) increases

Remember:

The saturation flow value cannot normally be altered by a traffic signal engineer. It is an intrinsic characteristic determined by roadway width, grade and other environmental factors.

Measurement of Flow

An approach to signals has a stream of 8 cars in 60 secs



So flow, q = 8 veh / min = 480 v p h

If cycle length, C = 90 secs

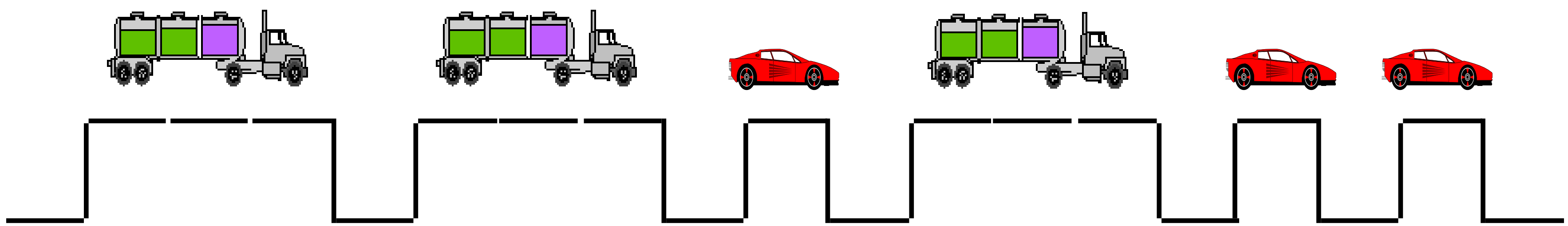
green time, g = 25 secs

Saturation flow, s = 1800 vph

Then $DS = \dfrac{q * C}{s * g} = \dfrac{480 * 90}{1800 * 25} = 0.96$ = 96%

Measurement of Flow

An approach to signals has a stream of 6 vehicles in 60 secs



Now flow, q = 6 veh / min = 360 v p h

If: cycle length, C = 90 secs

green time, g = 25 secs

Saturation flow, s = 1800 vph

$$\text{Then DS} = \frac{q * C}{s * g} = \frac{360 * 90}{1800 * 25} = 0.72 = 72\%$$

In the last example, the Traffic Density (Degree of Saturation) is still quite high (~100%) but our calculation gives only a reading of 72%.

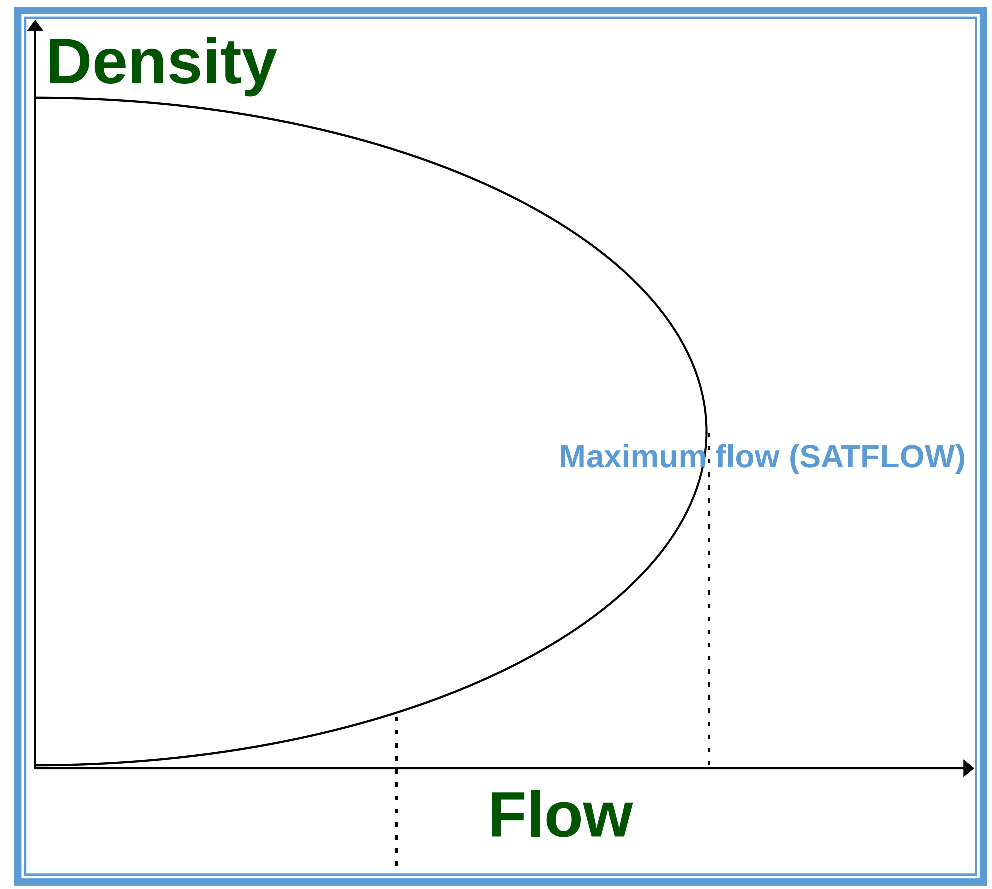
It is apparent that the simple equation $DS = qC/sg$

is NOT suitable for real-time variable mix traffic flows.

Some Flow Relationships

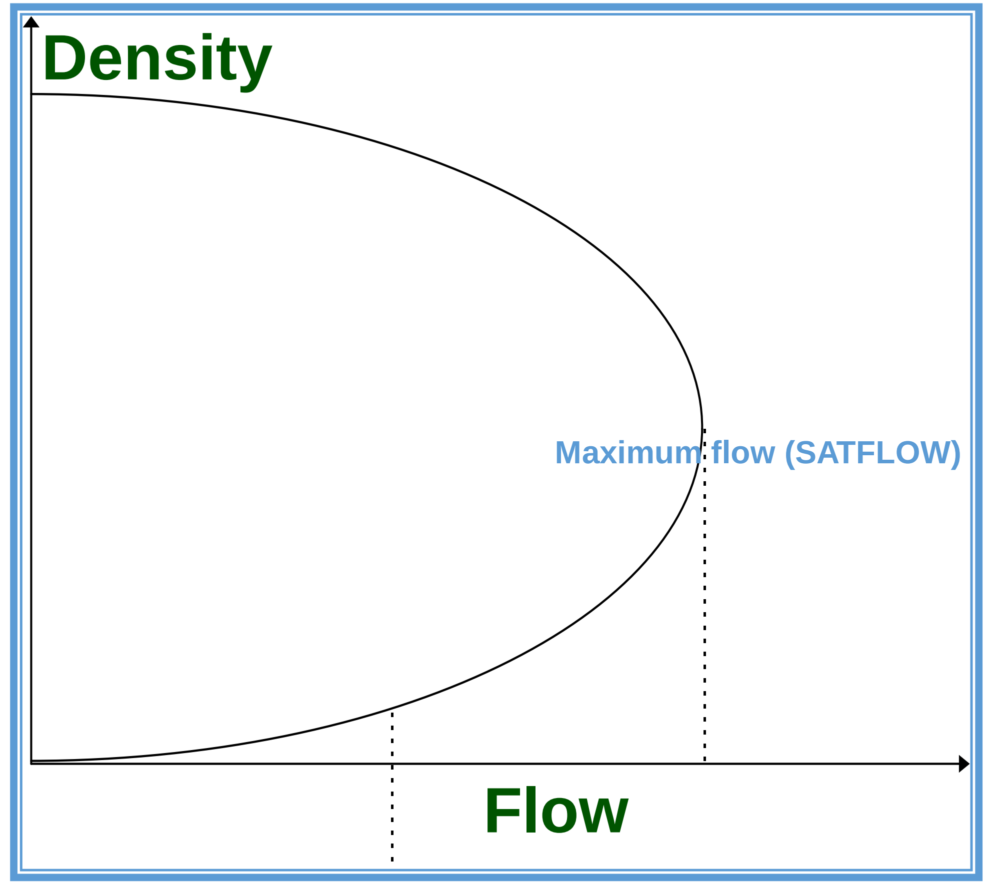
If we plot Traffic Density v. Flow we get “strange” relationship as depicted by the graph >>>>>>>>>

Note how the curve “doubles back”. For any value of flow there are two values of Density



Flow Relationships

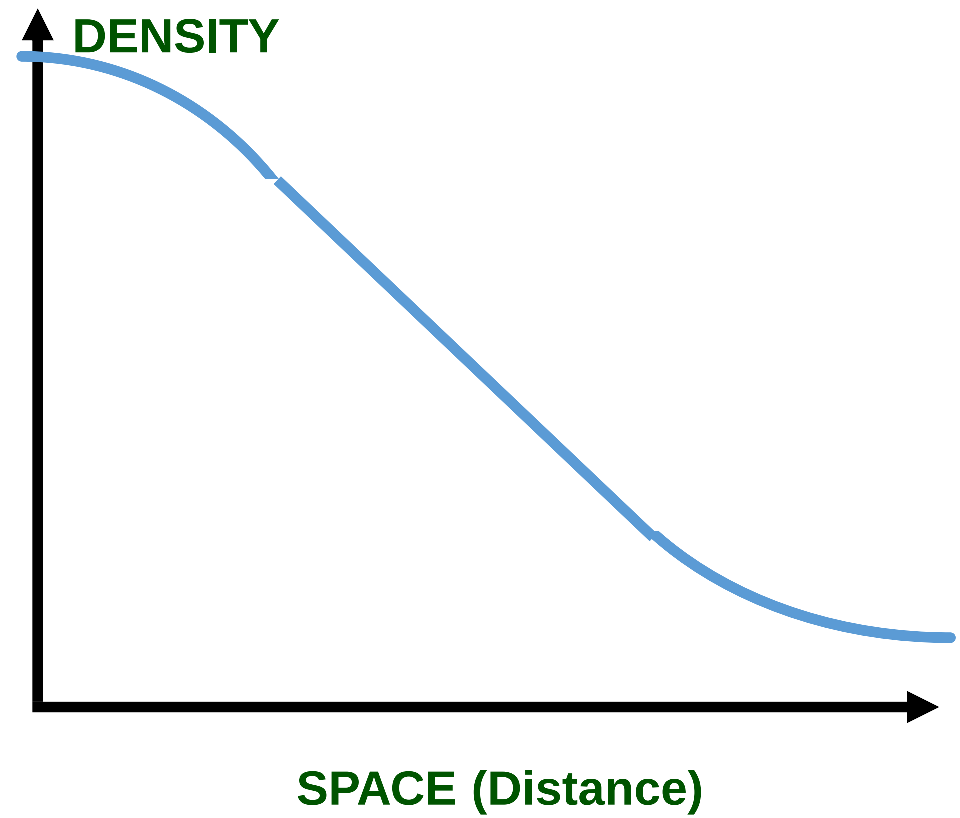
Once again flow is a very poor measure of traffic density. A flow of 600 vph could mean light flow or oversaturated flow (i.e. “crawling” traffic)



VEHICLE SPACE

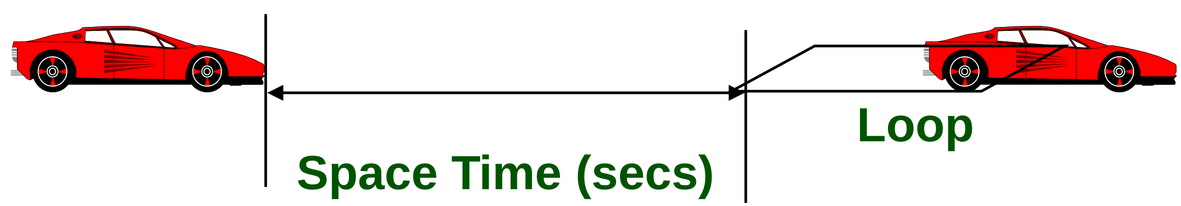
One of the “Secrets” of SCATS is the discovery of the relationship between traffic density (DS) and vehicle space. It is:

- Almost linear
- Without binomial values
- Largely insensitive to vehicle mix (type and length)



VEHICLE SPACE

However it is difficult to measure space distance in “real time”. It is much easy (with a loop detector to measure SPACE TIME (i.e. the time between vehicles OR the detector OFF time)

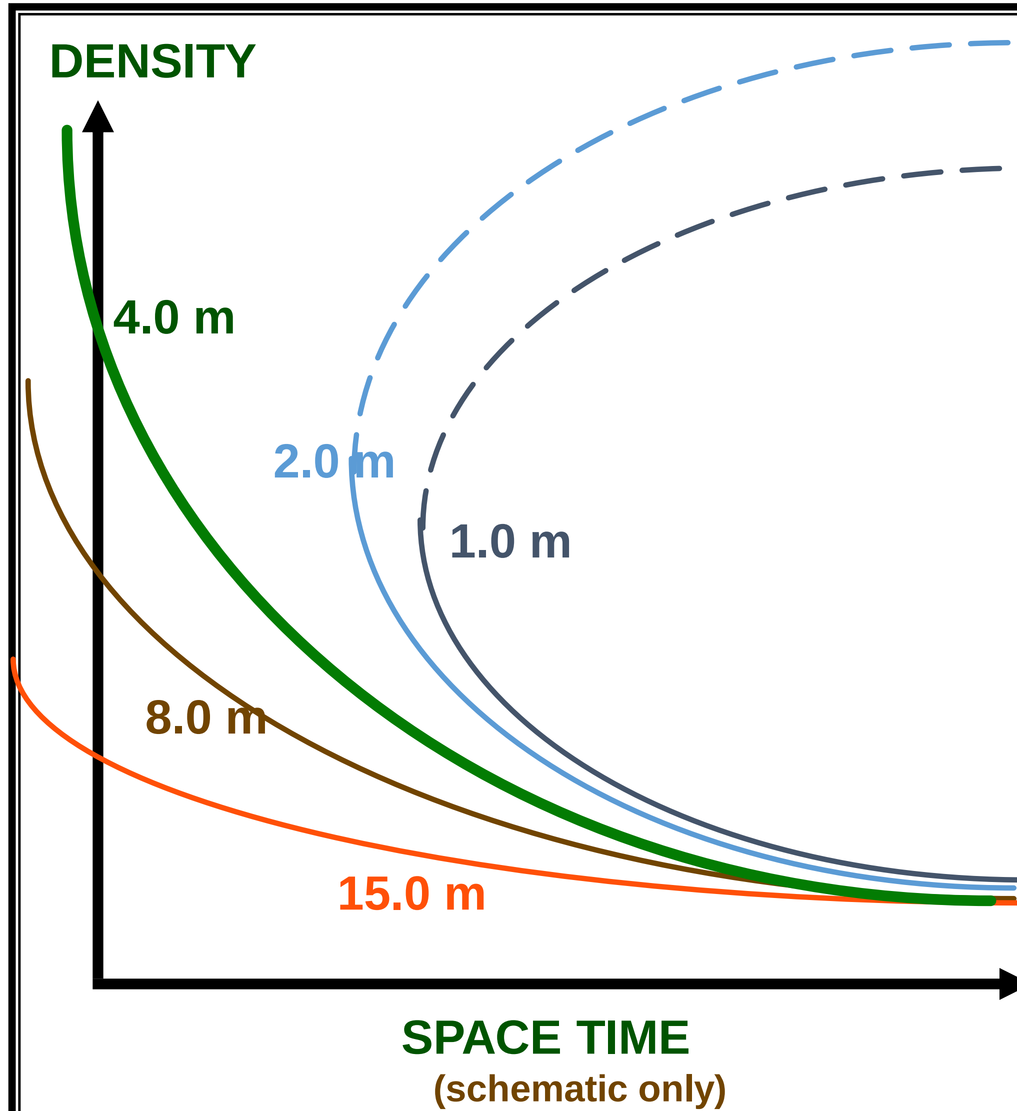


VEHICLE SPACE

However, the actual space time measured depends on the detection zone (loop) length.

Note that short loops tail back (at high DS they can have long space times). Long loops go “blind” (i.e. zero space values even at moderate densities.

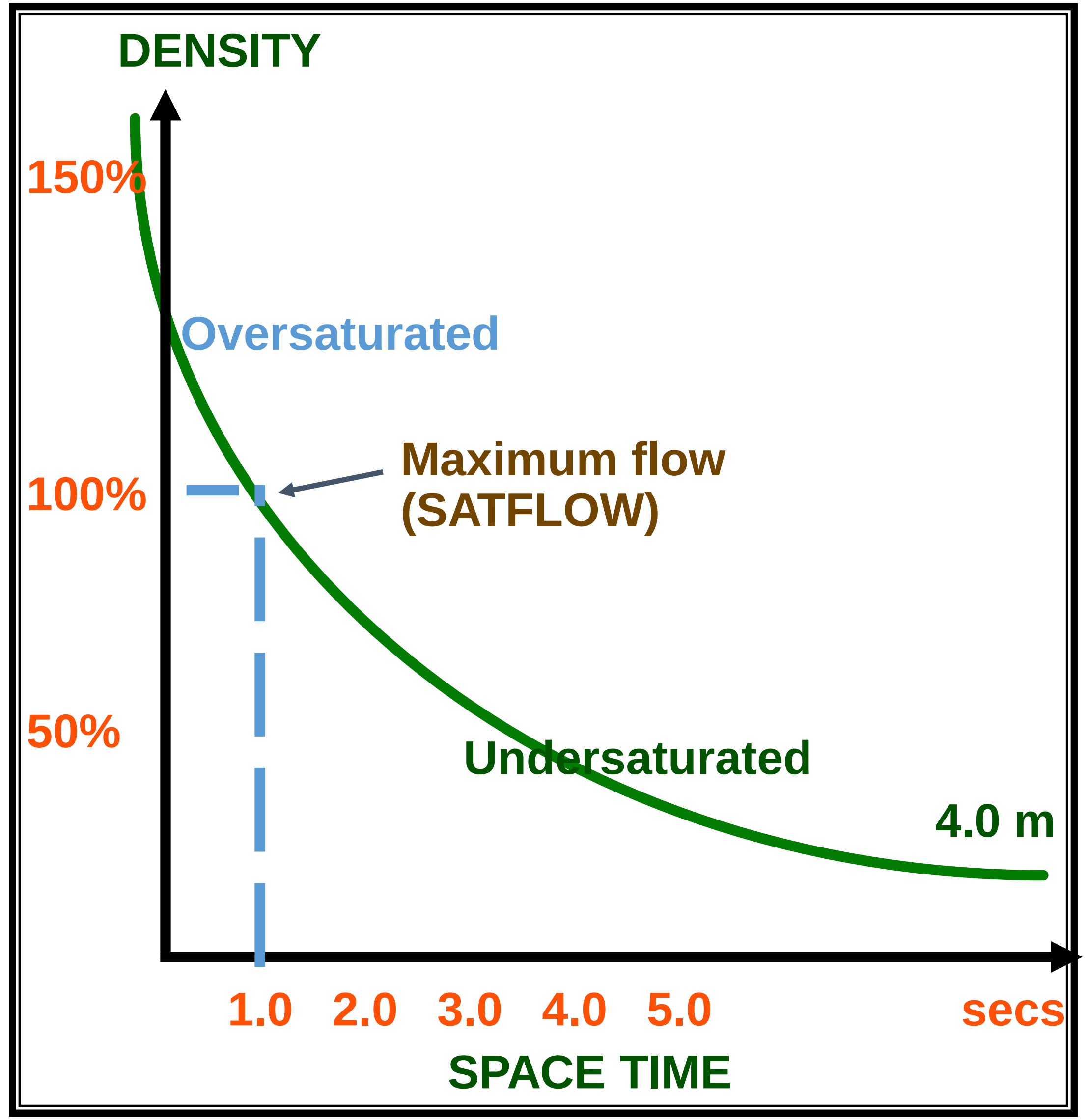
A 4.0 m loop is the optimum (zero space is not recorded until DS is well into oversaturated conditions.



VEHICLE SPACE

Some important features of this relationship between DS and Space.

Typically a normal lane has a SATFLOW of 1800 vph and an optimum space time of 1.0 secs.



OPTIMUM SPACE

The average space between vehicles during a period when maximum flow (SATFLOW) is achieved is called the Optimum Space Time and is typically 1 sec for a wide range of vehicle mixes and lane geometry.

SCATS continually (every cycle) measures the flow and space time in each specified lane and stores the maximum flow and its associated optimum space time for each 24 hr period.

WASTE TIME

All drivers leave some space between them and the vehicle in front - even in "bumper-to-bumper" conditions.

In undersaturated conditions drivers (on average) will leave a greater space - s than the Optimum Space time - t between them and the vehicle in front.

If we call this difference an average WASTE time. Then,

$$\boxed{w_{av} = s - t}$$

WASTE

The total WASTE for the lane is therefore:

$$W_t = (s - t) * n$$

where n = number of vehicles passing.

A SCATS controller actually measures the total Space Time (T) where

$T = s * n$

So the total Waste Time is now:

$$\boxed{W_t = T - t*n}$$

Degree of Saturation Definition

In SCATS we define Degree of Saturation as:

The ratio of the NON-WASTED time to the TOTAL time available for a lane.

If there is no “WASTED” time (i.e. maximum efficiency), then the lane must be running at SATFLOW

DS

The NON-WASTED time is simply the total green time available - "g" less the actual WASTED time:

$$U = (g - W_t)$$

Therefore:

$$DS = U / g$$

$$= (\cancel{g -} W_t) / g$$

DS

But remember: $\boxed{W_t = T - t*n}$

So:

$$\boxed{DS = [g - (T - t*n)] / g}$$

This formula "drives" SCATS

DS

$$DS = [g - (T - t*n)] / g$$

Just check this formula:

["t" - Optimum space time, is a constant (for each 24 hr period)]

- If "T" total space time increases, DS decreases
- If $T = t * n$, then $DS = g / g = 1.0 = 100\%$
- If $T > t * n$ then $DS < 100\%$, i.e. undersaturated
- If $T < t * n$ then $DS > 100\%$, i.e. oversaturated

SCATS can measure the Degree of Oversaturation !

DS

$$DS = [g - (T - t*n)] / g$$

This is the basic formula. There are many modifications to this formula to accomodate the myriad of situations that occur in real time adaptive system.