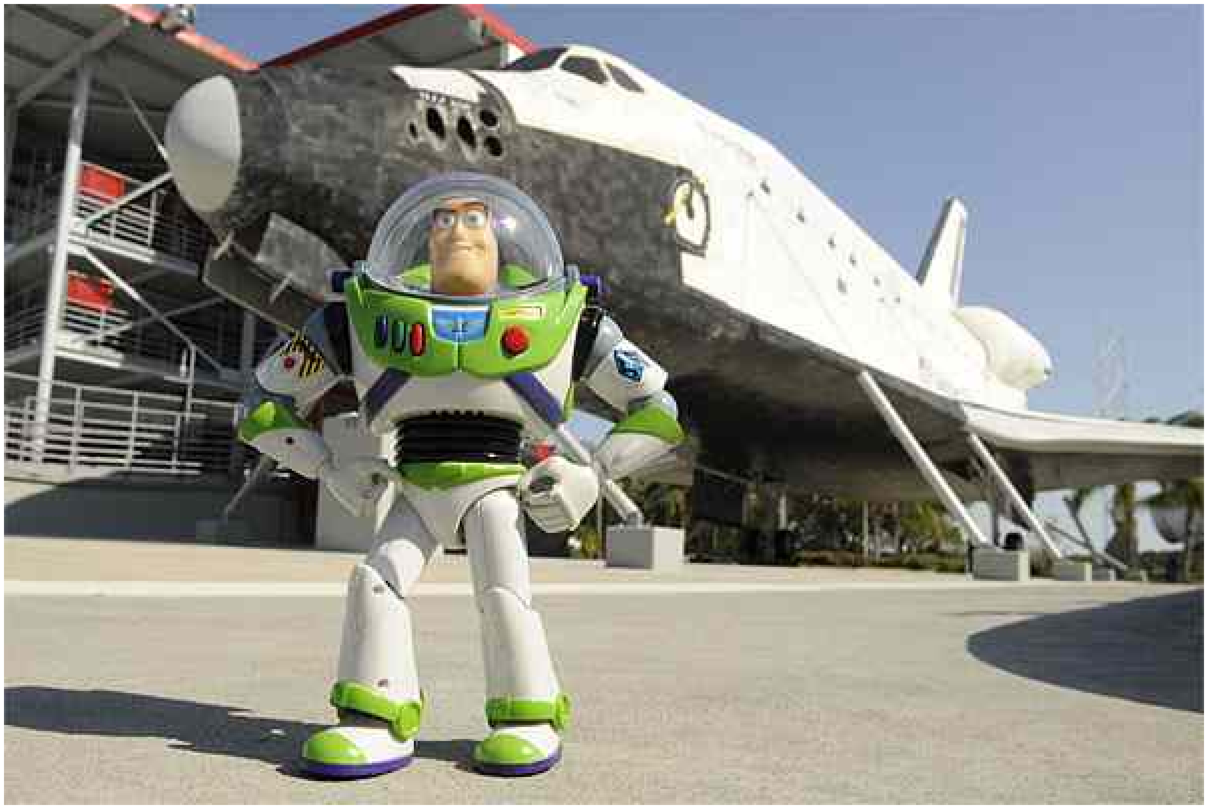
"To infinity ... and beyond!"



Quick Wiki check on non-rocket space launch

- Space tower – too heavy
- Space tether – I hate waiting for nano tubes
- Inflatable tower – cool, but who pays the helium bill
- Space fountain – cool, but I hate projectiles
- ...
- That's all folks ?

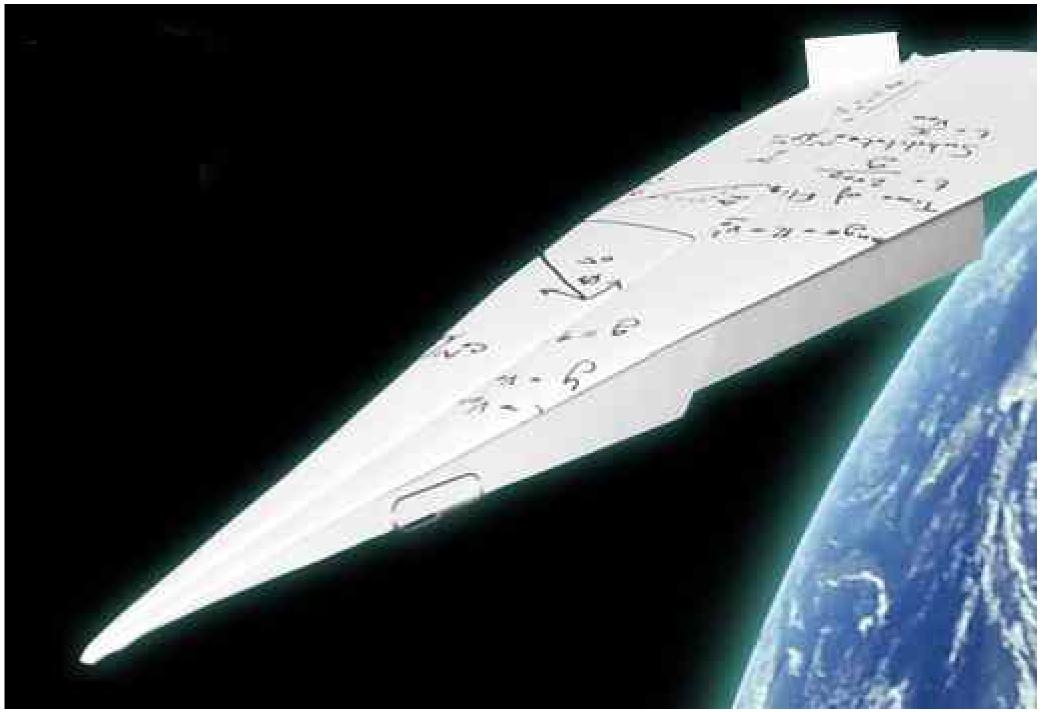
Rockets and balloons are boring, rubber bands and paper clips too ?

What about space towers?

It is now your turn to say:

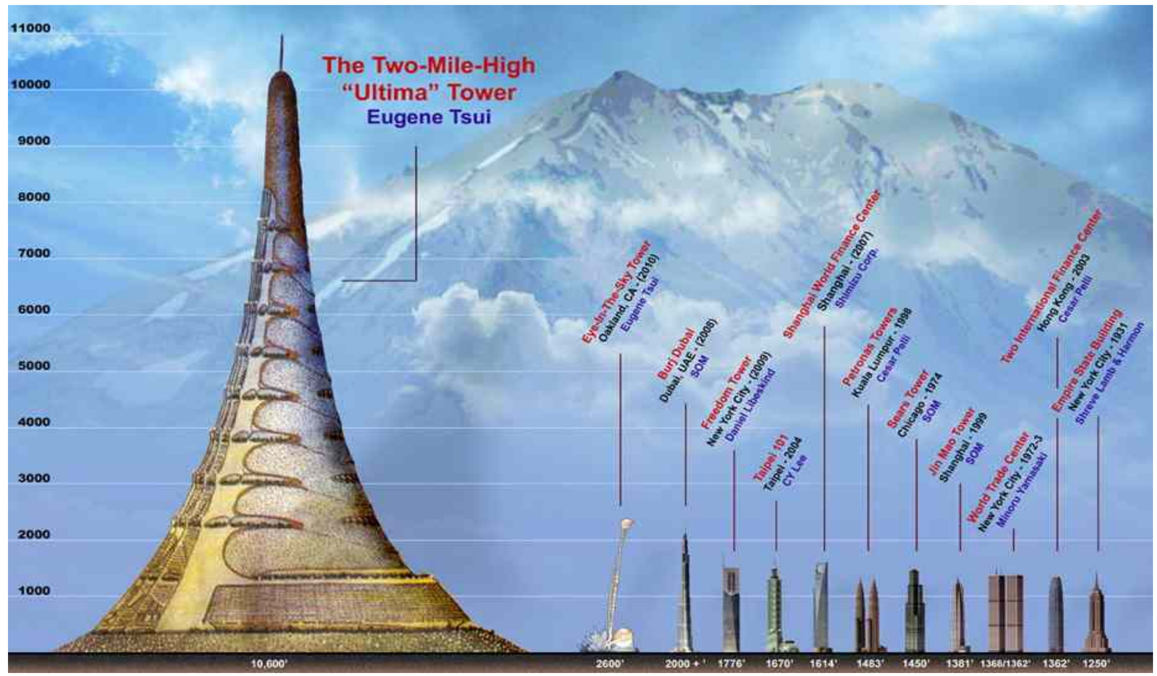
Are you nuts?

Building a low cost Space Hose/Tube/Pipeline just for winning the N prize?



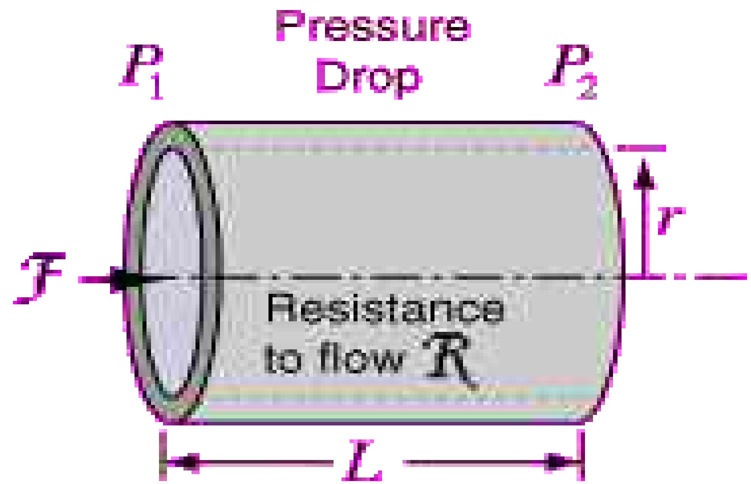
Tell me the real problem ...

Supporting the structual weight – also in vacuum !



bottom-up, top-down, ... or **continuously ?**

BTW what is flow resistance ?



Cool, it causes a pressure drop

= speed increase (Bernoulli)

and acts continuously against the flow !

What happens if you use a thin PE (Polyethylene) Film Tube open at the end?

- cool, now the pressure drop is gone ?
- in such a tube there is always atmosperic pressure
- up to the vacuum in space - well not completely?
  - still hydrostatic pressure change due to different height
  - we need a pressure diffusor at the end - remeber we are almost in vacuum there
  - there needs to be a light surpressure in the entire hose to prevent collapsing
  - and we need some lift at the top also – remember the N-price payload to make Paul happy ?
- but where is/goes the flow resistance ?
- it now provides a force on the Tube
  in the direction of the flow (wall effect) !
- it is working a little bit like a circular upright flag
- well, then lets put the hose

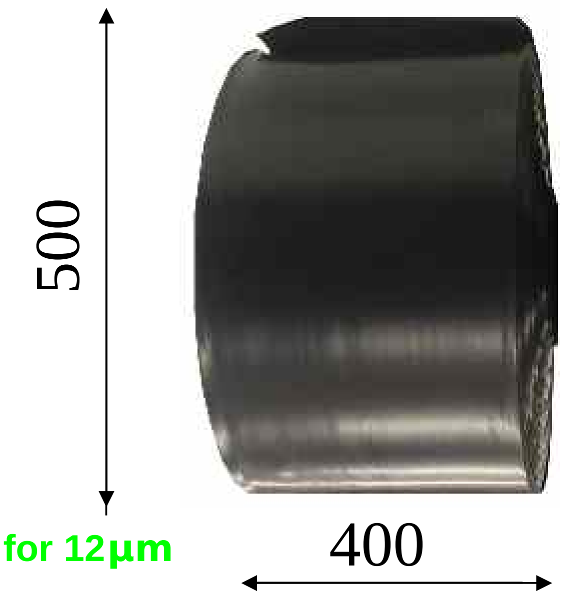
upright and start blowing ....

Does this really work ?
Let's do some (simple) math ...

- PE has a density of approx. 0,9g/cm³
  - it swimms on water, which is good when it lands on the ocean
- PE Foil can be produced down to a few µm thickness
- Let's asume 4µm thickness
  - a little bit low, but possible
  - 12-25µm you can buy around the corner
- Let's asume a hose diameter of 10“

=> 250mm diameter gives a handy

foil roll of 400mm width and 500mm diameter



- Gives 283 kg for a 100km hose
  - maybe 1t if you buy it at the next grocery
- **this still needs quite a lift, doesn't it ?**

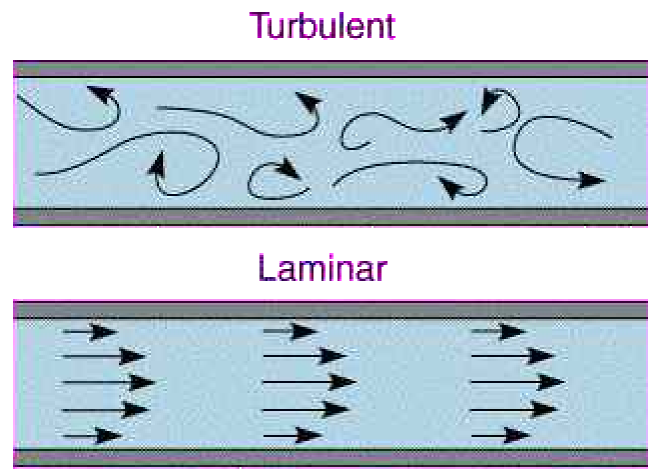
PS: for the N prize budget 1 cent/m=1000 EUR before hard negotiation, but for 12µm

4 µm would be far less material, and PE foil is also reusable and has recycle value

Let's flow some air now

Check first for laminar or turbulent flow – with

Mr. Reynolds: $Re = \rho D v / \eta$



- ρ ... density (Air at 0^0C 1,293kg/m³)
- η ... dynamic viscosity (Air 1.78×10^{-5} Pa.s)
- D ... diameter
- v ... velocity

Border for Turbulent Re>2320

Maximal Laminar Velocity for our hose:
2320*0,0000178/1,293/0,25=0,03m/sec=0,11km/h

= far too slow, hence always **turbulent** air flow

OK, but how big is the flow resistance?

Pressure loss: $\Delta p = \lambda \rho v^2 L / 2D$

λ ... friction coefficent

Getting λ is not so easy – Coolbroke Equation, Moody Diagram, Blasius, Nikuradse,...

But we know already Δp_{min} – we have to lift the damned **283kg** which means a resistance of **2773N**

=283kg*9,81m/s² gravity acceleration – let's asume it is constant for these 100km

But we don't know the velocity either – don't panic – iteration is on it's way!

Pressure/lift goes with the v^2

= good if thicker foil needed (4x weight = 2x speed)!

Some more assumptions ...

Let's jog to space v=3,5m/s=12,6km/h

eg. going to the 100km top is a plain 8h job

- no need for overtime in case they have trade unions there already
- and we don't like ballons overtaking

Re=1,293*3,5*0,25/0,0000178=**66.162** which means definitely turbulent flow

Q&D with Blasius ($2320<Re<10^5$) **λ**=$0{,}3164/Re^{0.25}$=**0,019728**

Coolbrook can do better: Roughness k for Plastic surface 0,0015-0,007mm

Relative Rougness k/D=0,0015/250=0,000006

then Moody Diagram gives for our Re:

λ=0,02 ... means Blasius is also OK

I'm asleep already!
So what friction force do we get?

- $\Delta p = 0{,}002 * 1{,}293 * 3{,}5^2 * 100.000/2 * 0{,}25 = 60565 N/m^2$ (or Pa)
- This is 0,6 bar which would blow the hose (remember it is only 4µm thick and PE foil supports only 20N/mm² tearing tension = 200Pa) unless it would be Dyneema strengthed which has up to 4000N/mm² – see later slide
- But wait a moment – it is a hose NOT a pipe, meaning the hose pressure should be the external pressure (down to the vacuum in 100km) + a 100Pa surpluss (=50%security margin from tearing the foil) from a small diffusor at the end

So this pressure change can only be transferred to the hose as friction force (are we sure on this ?):

$F = p * A = 60.565 * 0{,}25^2 * \pi/4 =$ **2.973N**

which should be sufficient to hold **303kg - but we need only 283kg!**

The rest should be enough for some Hardware on the top,

and the N prize satellite too **- well, a Nano Satellite might work also ;-)**

What happens if the force is not with us?

1) max static pressure if hose is closed and entire weight on top

283*9,81/0,05=0,56bar

2) converts to extra velocity of flow?

Bernoulli has the answer:

$v=(2p/\rho)^{0.5}=(2*60.565/1,293)^{0.5}=307m/s$

almost speed of sound – not very realistic to happen - but maybe more tubulence?

such a hose seems to work like a de Laval nozzle (without real diameter change)?

3) converts to height (pressure) loss?

$h=v^2/2g=307^2/2*9,81=4.774m$

=4,7km < 5% of 100km

Simply passing the friction force to the hose is the most realistic solution ?????

.... better ask daddy before giving it a try :-)

How much power do we need ?

Air flow: $Q=vA$

$Q=3{,}5*0{,}25^2\pi/4=0{,}17m^3/s=$**$618m^3/h$**

Hydraulic Power: $P=\Delta p*Q$

$P=60565*0{,}17=10.405W$

Engine Power=P/w=**15kW**

w .... efficiency (approx 0,7)

Nothing really exotic (and easy borrowable) .... are we **Done ?**

PS: For the N prize budget:

run it for 10 days =240x15=3600kWh costing about 500 EUR before hard negotiation

Blowing into the vacuum ?

Ideal gas law: pV=nRT or simplier:pV/T=constant

Bottom: T=293K p=10^5Pa Q=0,17m^3/s

instead of V we use Q=V/t

time is same top and botton + continuity law

Top: T=183K (-90^oC) p=100Pa

Q on top:100000*293*0,17/100/183=272,19m^3/s

but we have only a 0,05m^2 to blow out

This would mean 5367m/s – which is unrealistic

Expansion of air to vacuum gives only limited speed unless a de Laval nozzle is used, so we would need to increase hose diameter and we also need a light diffusor at the end (+100Pa)

How to handle speed difference ?

Bottom: r=6378km Top: r=6478km (+100km)

Speed difference $\Delta v=2*100*\pi/24=$**26km/h=7,27m/s**

so we have to blow harder anyway

to speed up top by bloowing also side and downwards during erection

but air on top is much faster due to expansion (see previous slide)

but where do we now get the **extra** weight from

if we really blow harder and prevent tearing the foil?

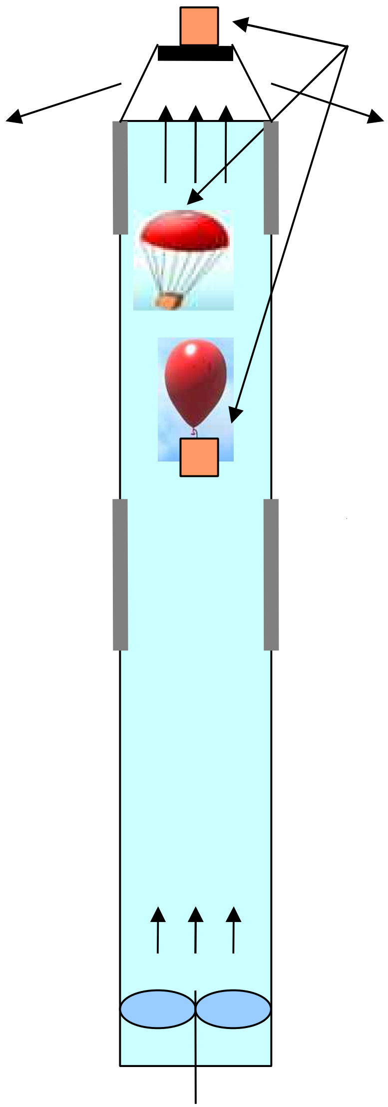
Could we blow a lightweight N-SAT into

ORBIT with a nozzle ?

And did I mention iteration for optimization

(diameter, blow speed, foil thickness,...) already ?

Some design thoughts ...



Here goes the N prize Satellite to pseudo geostationary orbit

orbital speed blowout in vacuum could be possible

better stay inside/nearby

- End diffusion can produce head lift for payload and slight downwards and sidewards flow for compensating speed difference top/bottom during erection and prevent downward momentum effect
- allows navigation of head by adjusting blow direction
- optional propeller on top could even produce electricity
- some regular Aluminium foil coating to get radar reflection
- use black PE foil for hose to have also chimney effect due to air warming from sun (warming happens also from turbulent flow)
- Propeller/fan/compressor at bottom
  - for creating 3,5m/s airflow
  - or more/less if we have to stand the wind,...
  - equals 620m³/h

What about strength?

- We (maybe) solved the lift/weight problem
- what about the stress on such an ultra thin hose?

winds, different velocities at different heights, condensation water, coriolis, rain

- maybe Pravda showed (once) the truth
- and Yuri was right ;-)
- add Dyneema strings as on the drawing ->

well it is also PE anyway and can be reused

- You get approx 2-3x the weight but 20x strength

the **extra** one, you remember ?

and don't forget to blow 2x harder

Dynema can hold 300-400km of it's **own** weight

enough security margin for our 100km ?

Lots of other Problems to be solved ....

- does it really work - ask an engineer AND a scientist :-)
- viscosity is a function of pressure and temperature
  - but all this is known for the atmosphere
  - Finite element calculation with 100m segments in a spreadsheet ?
- move it up/down the sky
  - in 1-2 days
  - maybe initial balloon lift or blowing extrusion to space
  - keep hose upright for 9 days (to win the N price)
  - get hose down in a few hours
  - maybe only 50km are better - not so cold there
- life time of such a very low cost plastic hose launcher
  - will be days to weeks only, maybe a few months
  - then recycle or burn it (plastic is pure oil anyway)
- **don't tell me the problem(s), tell me the solution(s) !**

Problems to be solved, cont ....

- better wait for a windless day like for a normal balloon launch
- pressure peaks, oszillation, turbulance losses
- chimney effect, condensates, limited UV resistance...
- Stability problems are **huge !**
  - you probably need hose pressure higher then atmosphere (+100Pa is peanuts)
  - you are still in trouble with vacuum, bending winds, speed differences, coriolis,...
  - strength of ultra thin PE foil limits design even with Dyneema
  - Straw bundle approach to give more strength
  - read the inflatable space tower patent to get **scared**

  (150m diameter, gyroscopes,..)
- 4µm foil calculated but currently 12-25/50/100 is standard
  - but 2-3x higher blow speed should still do the job
  - remember friction/lift increases with v^2
- **Zurg (friction) still is your friend, not the enemy !**

To be continued ...