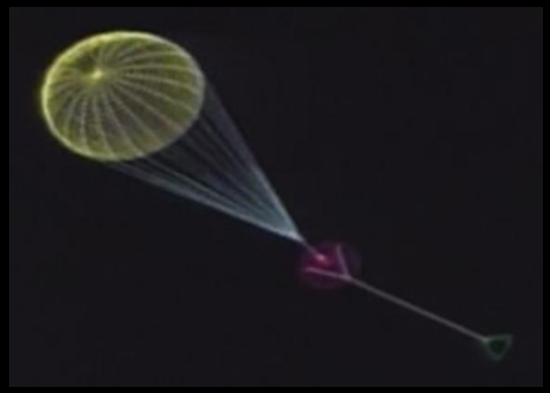


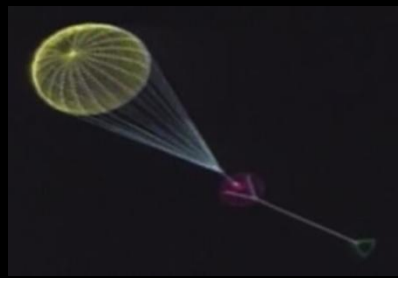
화성탐사선 착륙 프로젝트 #2

스피릿호의 낙하산 설계

조명 : AMOLED

2005006326 최종국
2005007277 오유석

❖ Contents

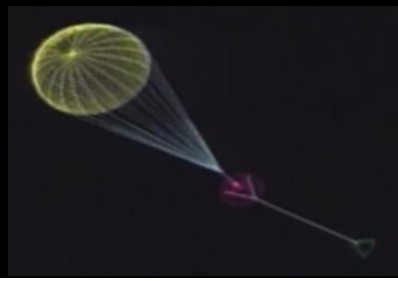


- Define Problem
- Numerical method

  1) EXCEL Solver

  2) MATALB™ : fmincon, GA, PS
- Graphical method
- Conclusion and Q&A

- Define Problem(1)



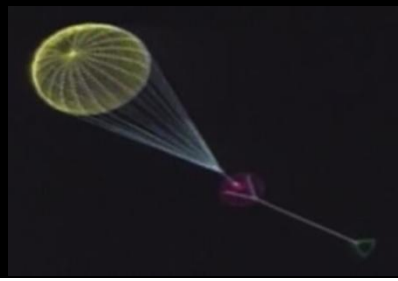
- Project/problem statement.

화성 탐사선 스피릿호를 화성에 안전하게 착륙시키려고 합니다.
스피릿호는 화성 대기권 진입 시 **450m/s**로 이동하고 있는데,
안전하게 착륙시키기 위해서 는 **50m/s** 까지 감속 시켜야합니다.

감속방법으로는 화성의 대기를 이용하여
낙하산을 이용하게 됩니다.
이때 **충분한 감속을 위한 낙하산의 크기와 disk와 cable이 각각의 한계응력을 넘지 않도록 하기 위한 설계**가 필요합니다.

마지막으로 우주선의 질량은 가벼울 수록
좋으므로 우주선에 탑재되는 **낙하산의 질량이 최소가 되는 설계**가 필요합니다.

- Define Problem(2)



- Data and information collection.

mars	
Density of air	0.013kg/m^3
gravity	3.72m/s^2

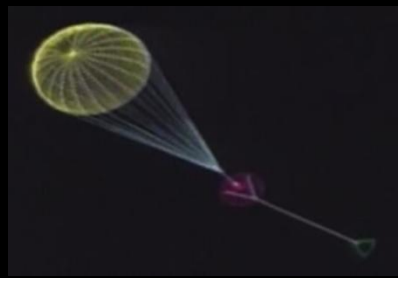
Parachute	
Coefficient of form	1.75
Disk (Nylon 66, Heat Stabilized)	
Tearing strength	82.8 MPa
density	120kg/m^3
Cable (technora fabric)	
Tensile strength	3000 MPa
density	140kg/m^3

Sprit	
mass	900kg
Initial velocity	450m/s
Final velocity	50m/s

(ref)

✓ http://ejectionseat.com.ne.kr/naceshelpk.htm
(반구형 형상의 공기 저항 계수)
✓보이스 오딧세이 – 저자 : 김형태
http://www.korearth.net/
(properties of mars)
✓ nasa.gov
✓matweb.com (properties of nylon)

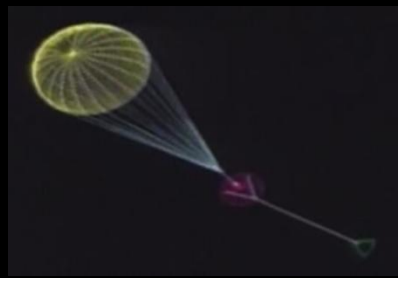
- Define Problem(3)



- Identification/definition of design variables.

d1 : diameter of disk
t : thickness of disk
d2 : diameter of cable
l : length of cable
n : number of cable

- Define Problem(4)

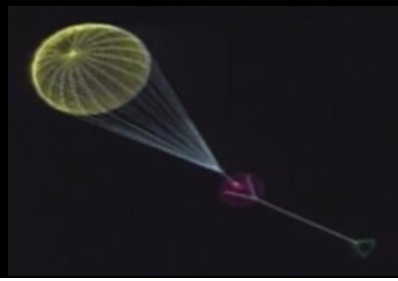


- Identification of a criterion to be optimized.

  - minimize weight(or mass) of parachute

$$f = \frac{\pi}{2}\rho_{disk}td_1^2 + \frac{\pi}{4}\rho_{cable}NLd_2^2$$

- Define Problem(5)



- Identification of constraints .

$$g_1 = \sqrt{\frac{8mg}{\pi \rho_{air} C_d d_1^2}} - V_2 \le 0$$ (Final velocity)

$$g_2 = \frac{\rho_{air} C_d V_1^2 d_1}{8t} - \left(\frac{\sigma_{Y\_disk}}{S}\right) \le 0$$ (tearing stress of disk)

$$g_3 = \frac{4mg\cos\left(\arcsin\left(\frac{d_1}{2L}\right)\right)}{\pi N d_2^2} - \frac{\sigma_{Y\_cable}}{S} \le 0$$ (tensile strength of cable)

$$g_4 = -d_1 + 20t \le 0$$

$$g_5 = d_1 - 2L \le 0$$

$$g_6 = N(integer)$$

$$g_7 = -d_1 \le 0$$

$$g_8 = -t \le 0$$

$$g_9 = -d_2 \le 0$$

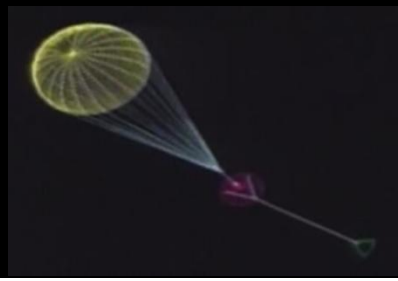
$$g_{10} = -L \le 0$$

$$g_{11} = -N \le 0$$

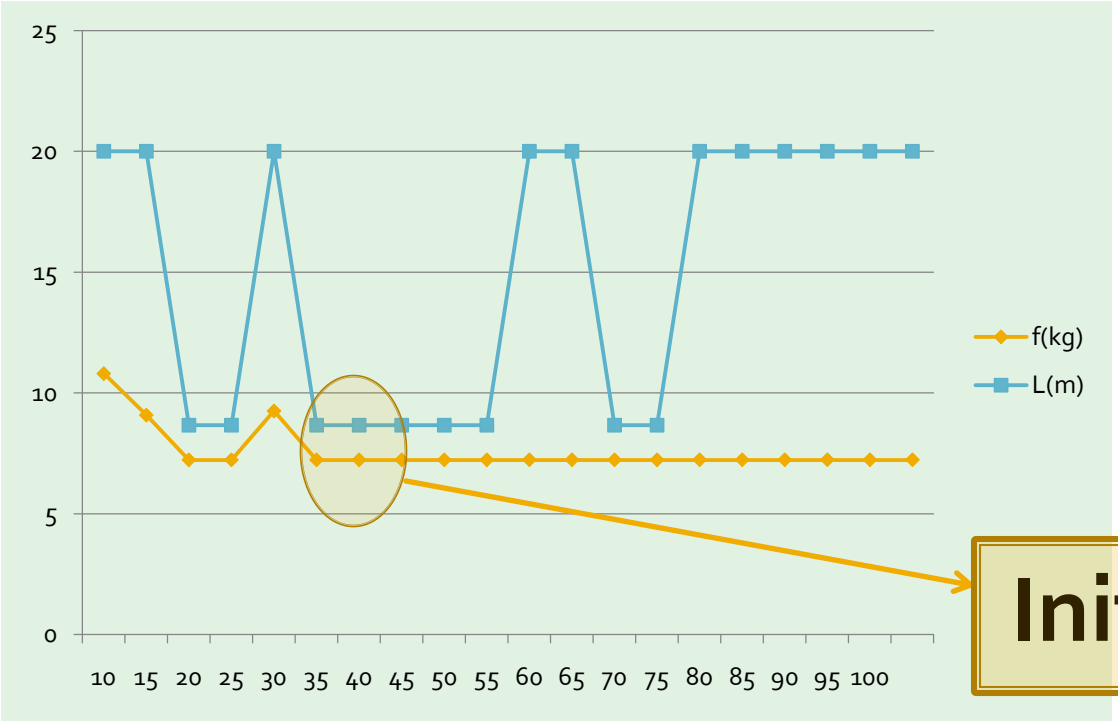
parachute		sprit		Disk(Nylon 66, Heat Stabilized)	
Coefficient of form	c	mass	m	Tearing strength	Sigma_disk
mars		Initial velocity	V1	density	Rho_disk
Density of air	Rho_air	Final velocity	V2	Cable(technora fabric)	
gravity	g			Tensile strength	Sigma_cable
-		-		density	Rho_cable

- k(safety factor)=3

Numerical Method

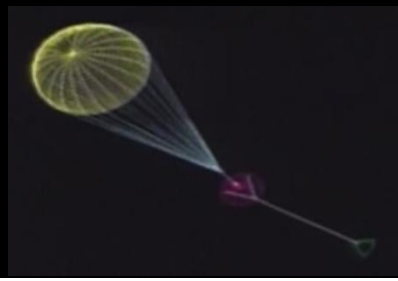


- Excel Solver



Initial 'N' =40

Numerical Method



- Excel Solver

5 variables
11 constraints

	Optimum value
d1(disk)	12.2434 m
t1(disk)	0.2555 mm
d2(cable)	0.3882 mm
L(cable)	8.6581 m
N(cable)	40
f	7.2237 kg

Numerical Method

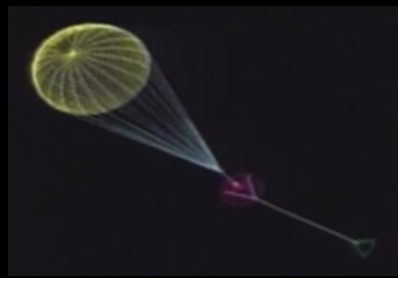
Properties		
Sigma_ny	82.8	MPa
Sigma_li	3000	MPa
C_d	1.75	
m	900	kg
g	3.72	m/s^2
rho_air	0.013	kg/m^3
rho_D	120	kg/m^3
rho_L	140	kg/m^3
S	3	
Tolcon	1.00E-06	
V_1	450	m/s
V_2	50	m/s

Design Variables		
initial		solution
10	d1(disk)	12.24340109
0.001	t1(disk)	0.000255452
0.001	d2(cable)	0.000388202
20	L(cable)	8.658075356
40	N(cable)	40

Object		
f	7.223703	kg

Constraints			
v	g1	0	Active
disk	g2	0	Active
cable	g3	2.40288E-07	Active
disk	g4	-12.23829205	Inactive
form	g5	-5.072749626	Inactive
integer	g6	40	Integer
	g7	-12.24340109	Inactive
	g8	-0.000255452	Inactive
	g9	-0.000388202	Inactive
	g10	-8.658075356	Inactive
	g11	-40	Inactive

Numerical Method



- MATLAB™ : fmincon

5 variables
10 constraints

→

	Optimum value
d1(disk)	12.2434m
t1(disk)	0. 2555mm
d2(cable)	0. 3362mm
L(cable)	6.1215m
N(cable)	41.8
f	7.2211 kg

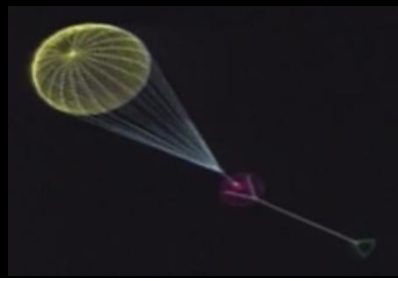
Numerical Method

Command Window

```
Optimization terminated: magnitude of directional derivative in search
 direction less than 2*options.TolFun and maximum constraint violation
  is less than options.TolCon.
Active inequalities (to within options.TolCon = 1e-006):
  lower      upper     ineqlin   ineqnonlin
                                     1
                                     2

x =

   12.2434    0.0003    0.0003    6.1215   41.8337


fval =

    7.2211


exitflag =

     5
```

```
output =

      iterations: 17
       funcCount: 115
    lssteplength: 0.5000
        stepsize: 1.1650e-004
       algorithm: 'medium-scale: SQP, Quasi-Newton, line-search'
   firstorderopt: 5.1019e+016
  constrviolation: -1.0000e+009 -1.2285e+011i
         message: [1x172 char]


lambda =

        lower: [5x1 double]
        upper: [5x1 double]
       eqlin: [0x1 double]
    eqnonlin: [0x1 double]
      ineqlin: [7x1 double]
   ineqnonlin: [3x1 double]

>>
```

Numerical Method



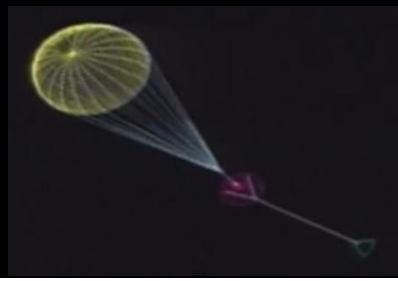
- MATLAB™ : GA

알고리즘을 사용할 때마다

(1) Optimization terminated: no feasible point found.
(2) Constraint function must return real value.
-> (1) or (2) error 발생

심한 비선형 함수 -> 해를 찾지 못하고 있음

Numerical Method



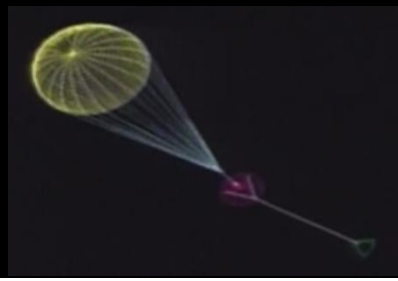
- MATLAB™ : pattern search

```
Command Window
Optimization terminated: mesh size less than options.TolMesh
 and constraint violation is less than options.TolCon.

x =

   38.1958   -0.0010    0.0022   20.0000    3.0000

fval =

 -274.9677

exitflag =

     1


output =

         function: @fun
      problemtype: 'nonlinearconstr'
       pollmethod: 'gpspositivebasis2n'
     searchmethod: []
       iterations: 5
        funccount: 1368
         meshsize: 1.0000e-011
        randstate: [625x1 uint32]
       randnstate: [2x1 double]
    maxconstraint: 0
          message: [1x115 char]
```

Optimization terminated: mesh size less than options. TolMesh and constraint violation is less than options.TolCon.

⇒ TolMesh & TolCon을 줄여도 constraint을 벗어나는 결과

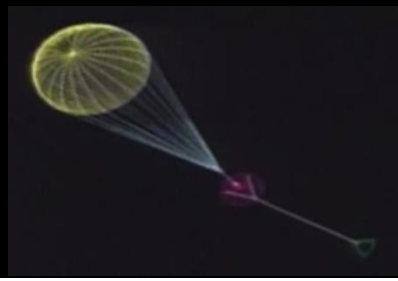
Compare



- Compare with last solution

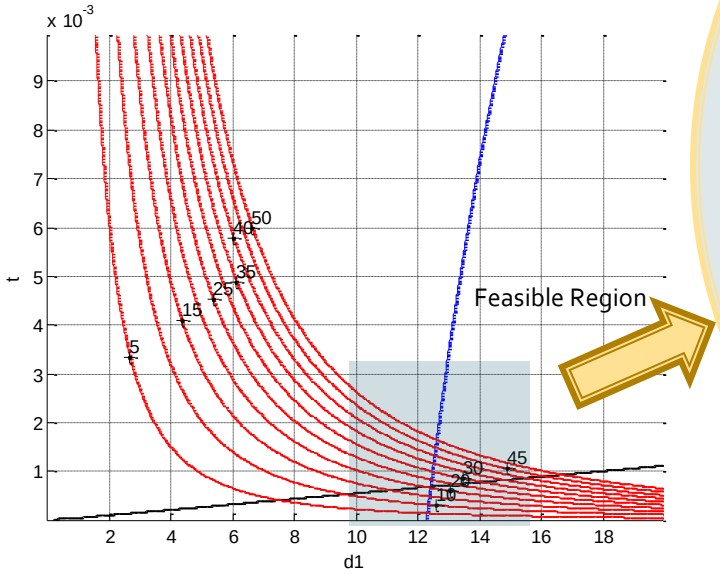
	Last solution	Excel solver	MATLAB™ : fmincon
d1(disk)	12.2m	12.2434 m	12.2434m
t1(disk)	0.7mm	0.2555 mm	0. 2555mm
d2(cable)	1mm	0.3882 mm	0. 3362mm
L(cable)	48m	8.6581 m	6.1215m
N(cable)	100	40	41.8
f	21kg	7.2237 kg	7.2211 kg

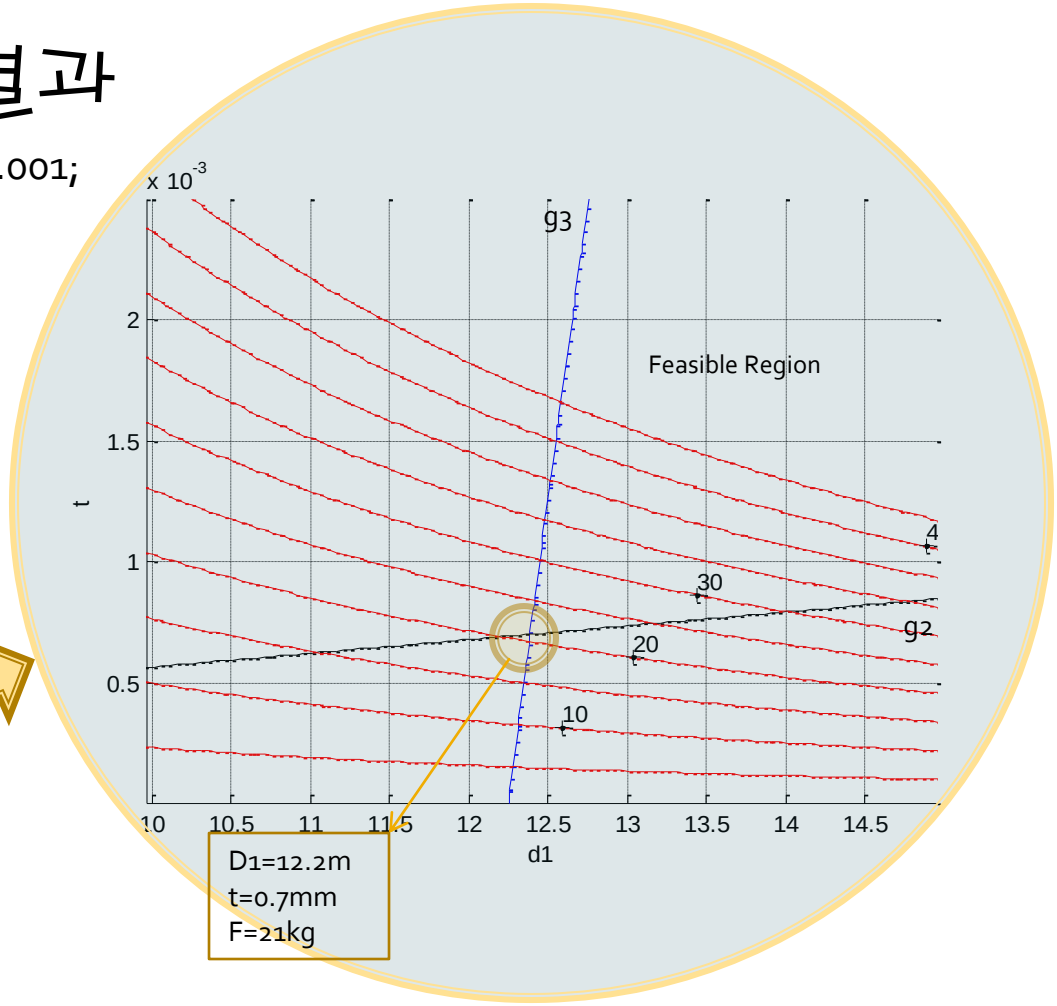
Graphical method



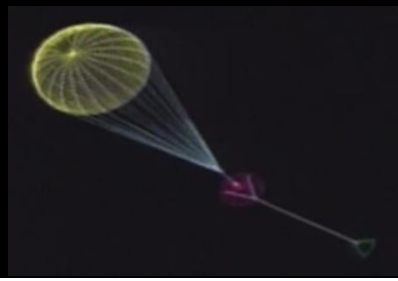
- 지난 프로젝트 결과

  => f(d1,t) : n=100; l=48; d2=0.001;



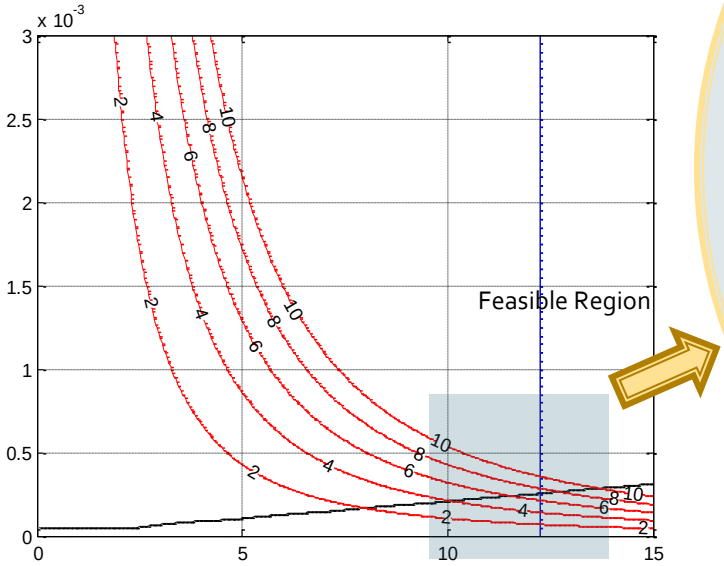


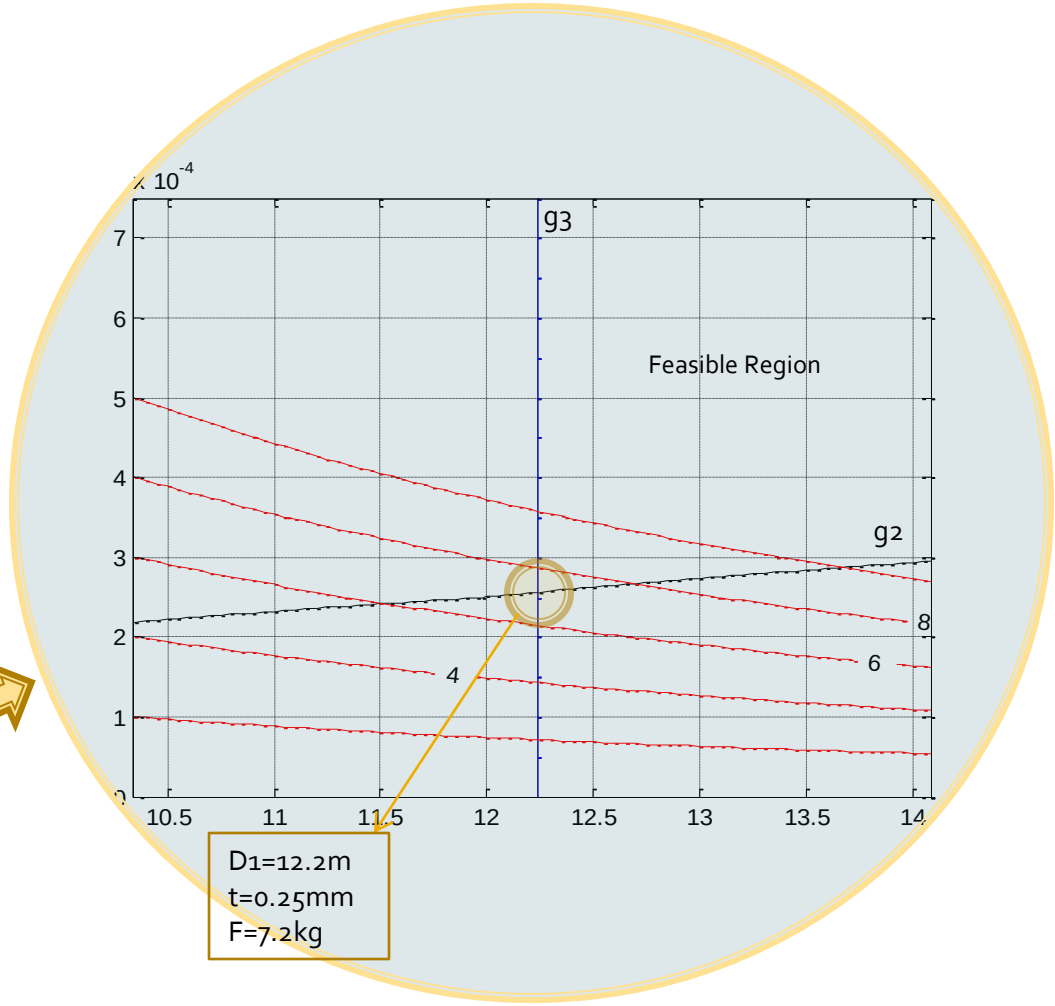
Graphical method



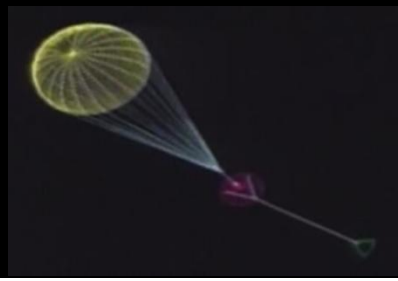
- Excel solver

  => f(d1,t) : n=40; l=8.6581m;
  d2=0.3882mm;



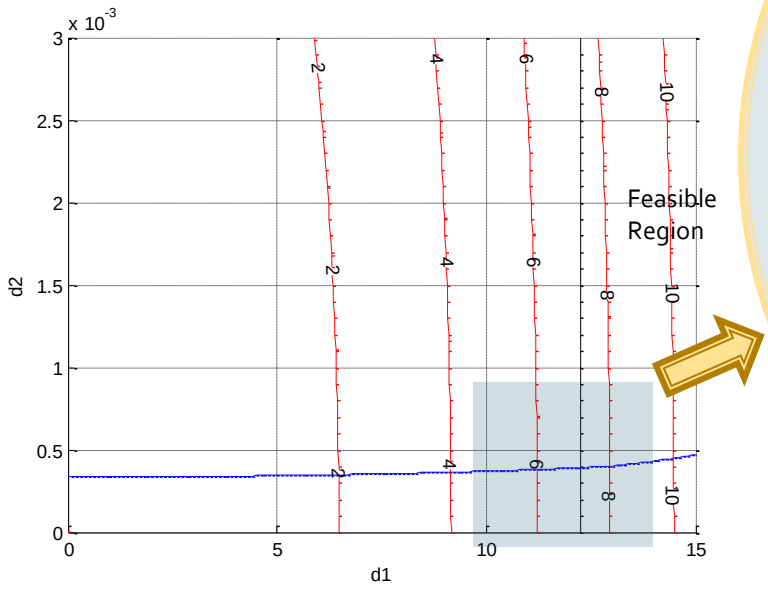


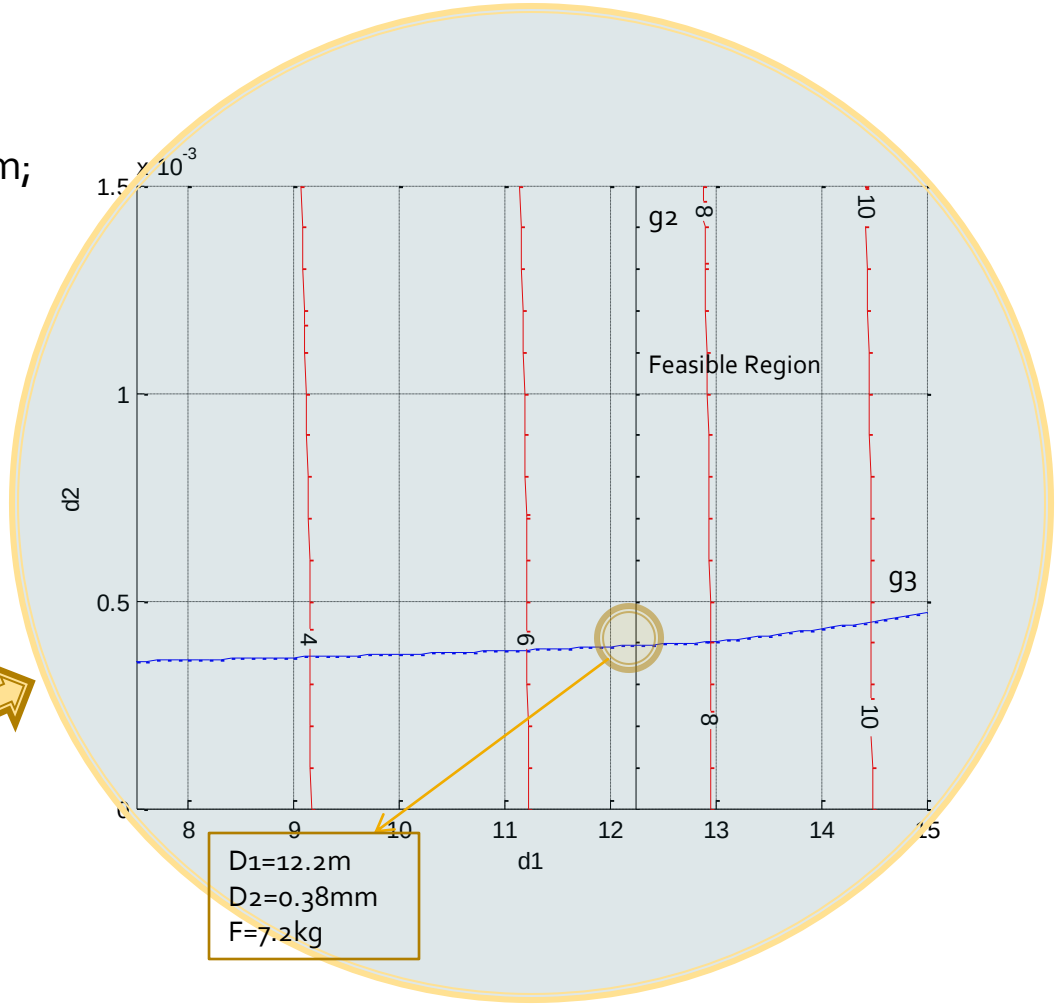
Graphical method



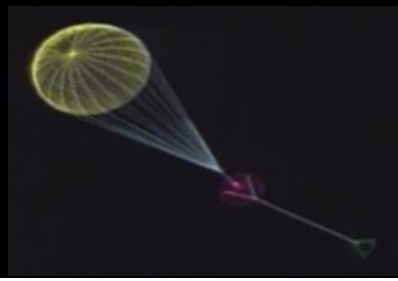
- Excel solver

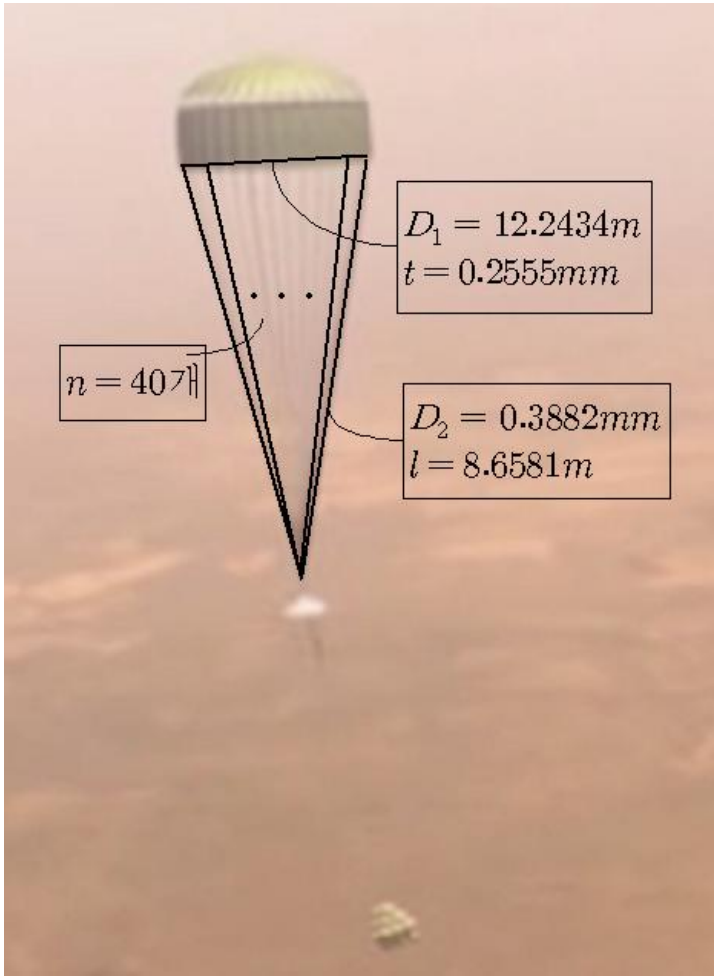
  => f(d1,d2) : n=40; t=0.2555mm;
  l=8.6581m;





Conclusion





<결론>

기존설계의 직경=9.1m

지난번 프로젝트의 결과 **21kg**에서
이번 프로젝트 **7.2237kg** 으로
=> **13.7763kg** 감소
(2변수 -> 5변수, 큰 폭으로 감소)

- 기존설계와의 차이

개선점 : 학부에서 배운 내용까지의
모델링이므로 추가적인
제약조건이 필요

Q&A

이상으로 AMOLED 조의
발표를 마치겠습니다.

감사합니다.