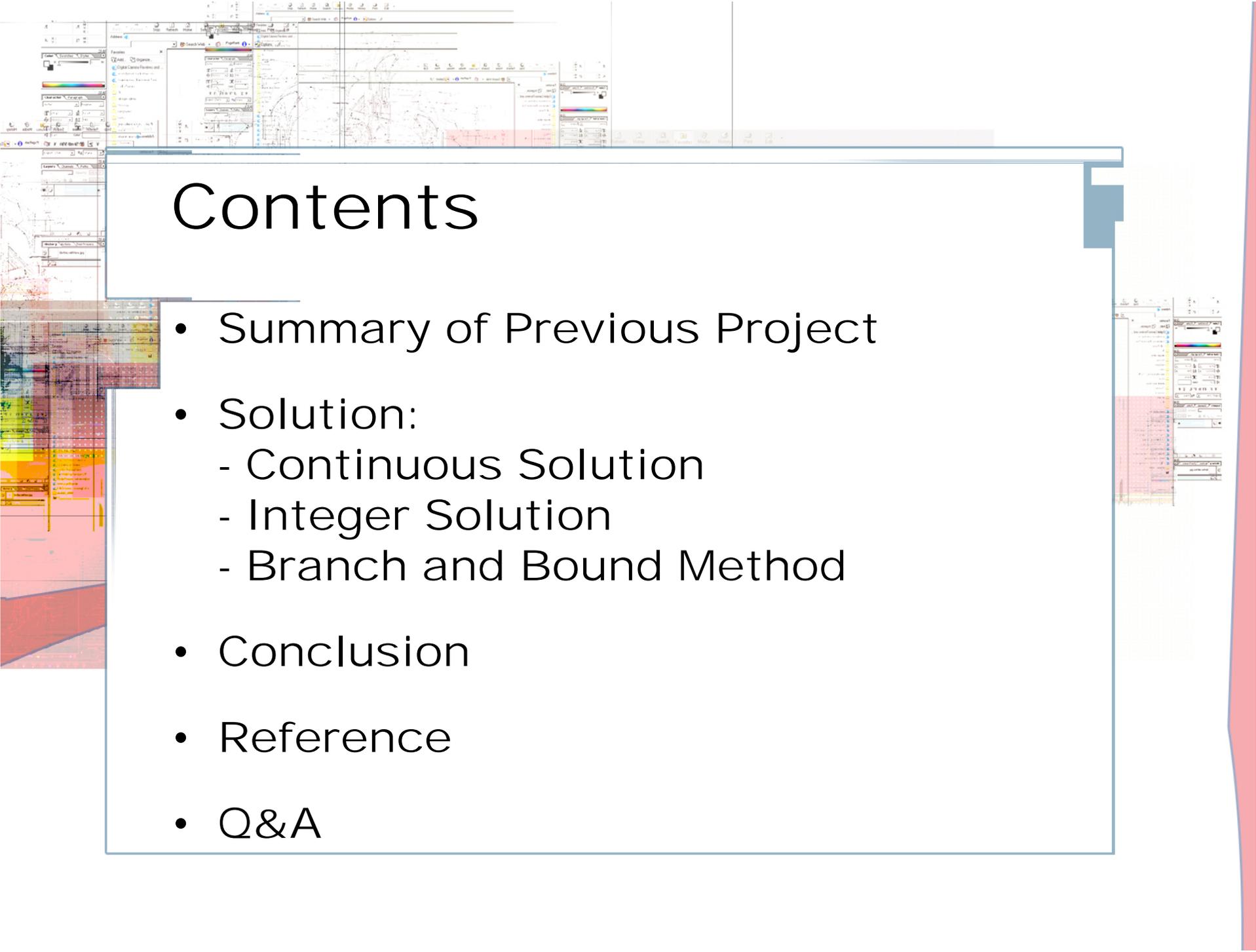
The background is a complex, layered composition. It features a grid of small white dots on an orange background. Overlaid on this are various technical drawings, including what appears to be a CAD interface with a 3D model of a rectangular object, and several sheets of paper with text and diagrams. The colors are primarily orange, red, and yellow, with some green and blue accents. The overall aesthetic is technical and modern.

# Optimum Design for Armor Plate

team B.L.V

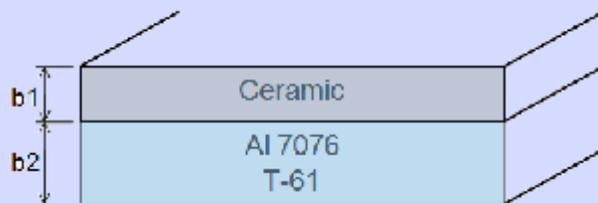
The background of the slide is a collage of various software interfaces and data visualizations. At the top, there are screenshots of what appear to be GIS or mapping software, showing maps with various layers and toolbars. Below these, there are more complex data visualizations, including what looks like a network diagram or a flow chart with nodes and edges. On the right side, there are more screenshots of software interfaces, possibly related to data analysis or simulation. The overall aesthetic is technical and data-driven.

# Contents

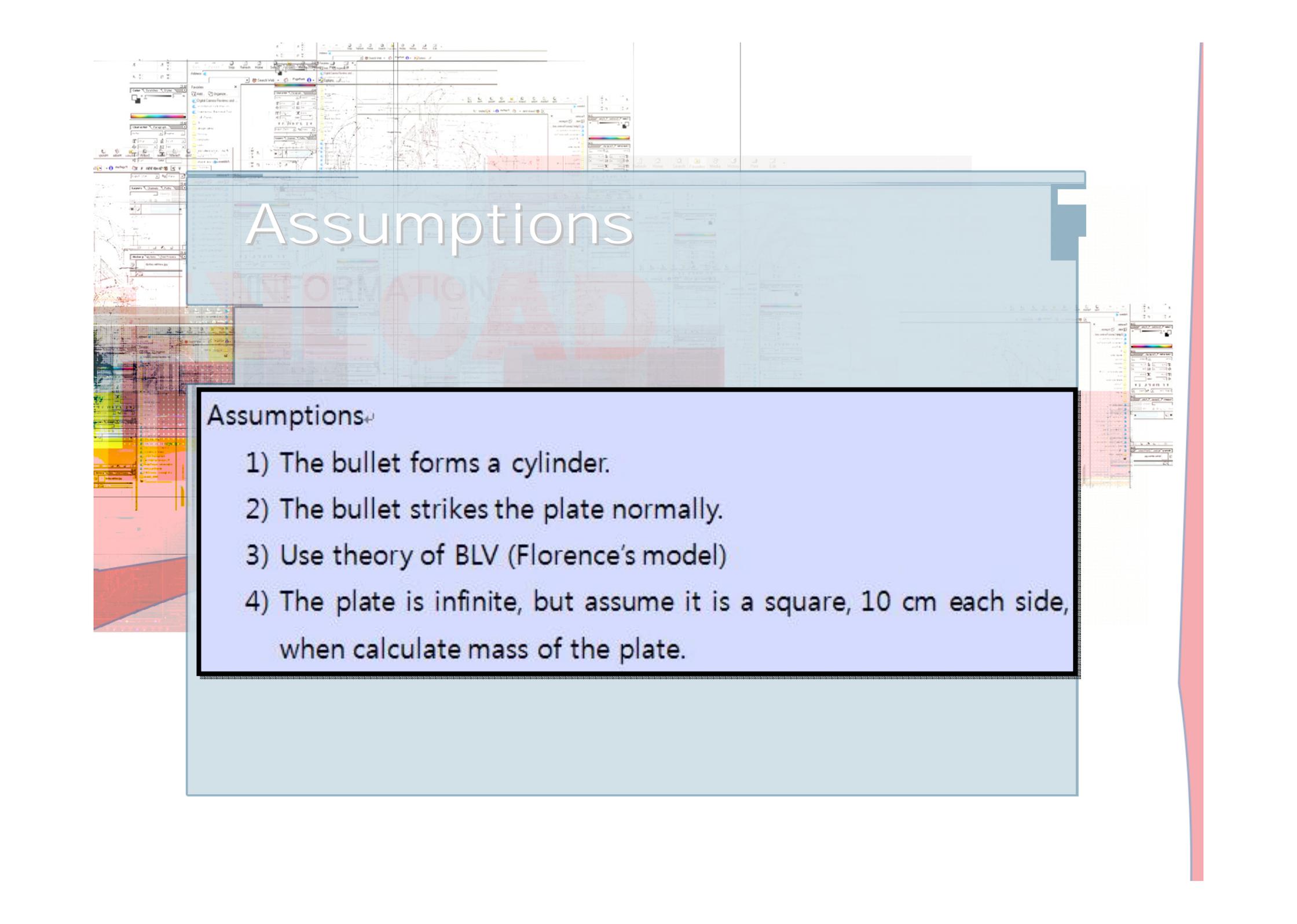
- Summary of Previous Project
- Solution:
  - Continuous Solution
  - Integer Solution
  - Branch and Bound Method
- Conclusion
- Reference
- Q&A

# Project Statement

Design an armor plate which can be attached to a car. A bullet forming a cylinder - 7.62 mm of diameter and 24g of mass - strikes the plate with velocity of 700 m/s. The armor has to have proof of this shot. The plate is a compound body of ceramic and aluminum, and the maximum total thickness of the plate is 20 mm. In industry, aluminum and ceramic plates are produced in 1 mm. Minimize the mass of this plate. Put factor of safety 1.1 to velocity.



<figure>



# Assumptions

## Assumptions

- 1) The bullet forms a cylinder.
- 2) The bullet strikes the plate normally.
- 3) Use theory of BLV (Florence's model)
- 4) The plate is infinite, but assume it is a square, 10 cm each side, when calculate mass of the plate.

# Formulation

$$\text{Minimize } m(b_1, b_2) = \gamma_1 A b_1 + \gamma_2 A b_2$$

$$(\gamma_1 = 3.96 \text{ g/cc} \quad \gamma_2 = 2.84 \text{ g/cc} \quad A = 10 \text{ cm} \times 10 \text{ cm} = 100 \text{ cm}^2)$$

Subject to

$$g_1 = (770)^2 - \frac{\alpha \epsilon_2 \sigma_2 b_2 z [(\gamma_1 b_1 + \gamma_2 b_2) z + m]}{0.91 \text{ m}^2} \leq 0$$

$$z = \pi (R + 2b_1)^2$$

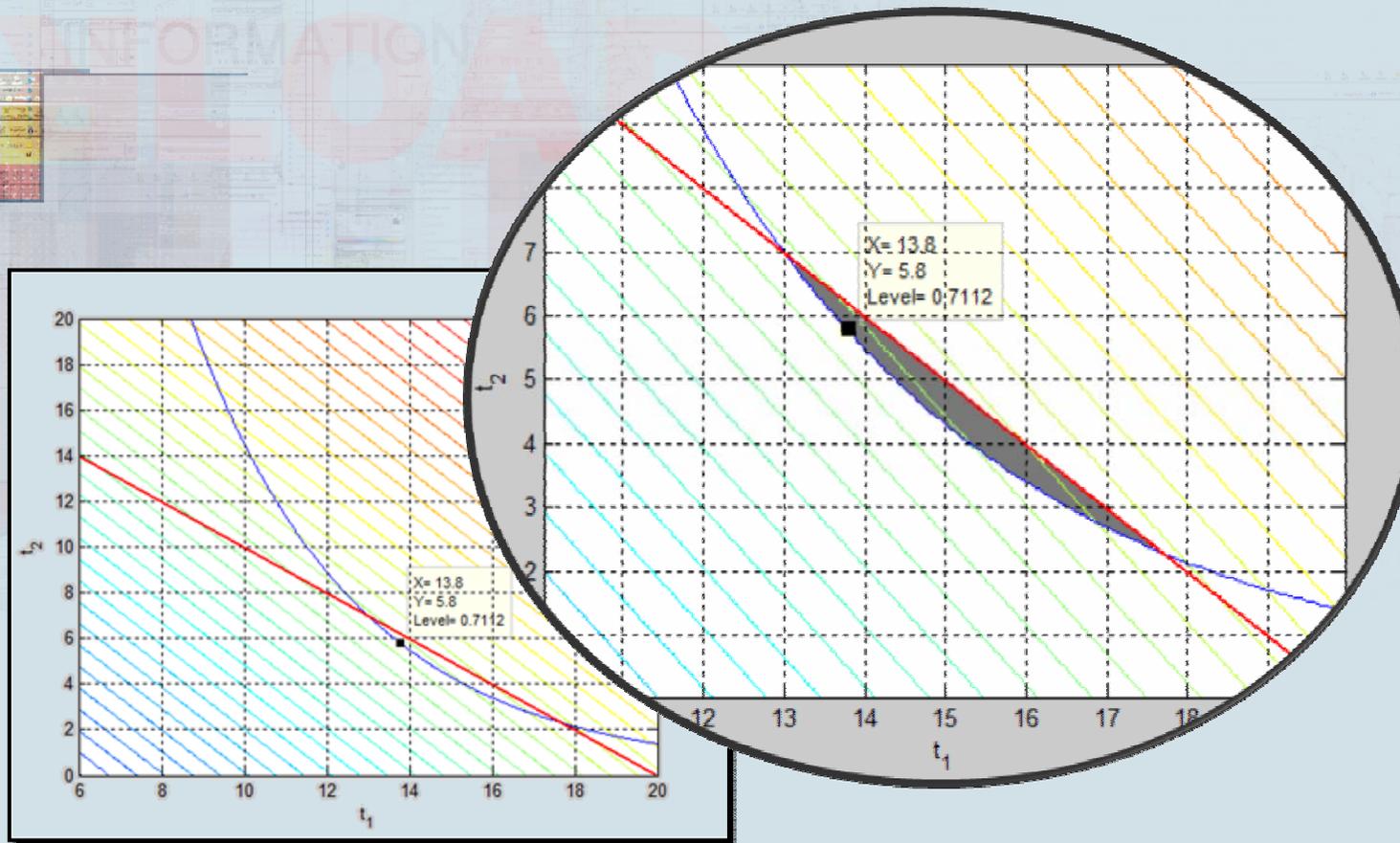
$$\alpha = 1$$

$$g_2 = b_1 + b_2 \leq 0.02$$

$$g_3 = -b_1 \leq 0$$

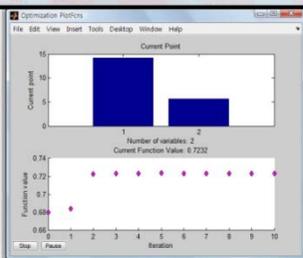
$$g_4 = -b_2 \leq 0$$

# Graphical Method



# Solution (by Matlab)

Solver: fmincon - Constrained nonlinear minimization  
Algorithm: Interior-point  
Problem:  
Objective function: @darmor  
Derivatives: Approximated by solver  
Start point: [10 10]  
Constraints:  
Linear inequalities: A: [1 1 -1 0 0 -1] b: [20 0 0]  
Linear equalities: Aeq: [] beq:  
Bounds: Lower: Upper:  
Nonlinear constraint function: @darmor\_constr  
Derivatives: Approximated by solver  
Run solver and view results  
[Start] [Pause] [Stop]  
Current iteration: 10  
Clear Results  
Optimization running.  
Optimization terminated.  
Objective function value: 0.7231988079846355  
Optimization terminated: first-order optimality relative error less than options.TolFun, and relative constraint violation less than options.TolCon.  
Final point:  
1 2  
14.229 5.624



Matlab	
b1	14.229mm
b2	5.624mm
function value	0.7232kg

```
-----  
Optimization running.  
Optimization terminated.  
Objective function value: 0.7231988079846355  
Optimization terminated: first-order optimality relative error  
less than options.TolFun, and relative constraint violation less  
than options.TolCon.  
-----  
Final point:  
1 2  
14.229 5.624
```

# Solution (by Excel Solver)

Excel Solver		Matlab	
b1	13.798mm	b1	14.229mm
b2	5.757mm	b2	5.624mm
function value	0.7099kg	function value	0.7232kg

			[mm]	initial[m]	optimum[m]
Thickness	ceramic	b1	13.79814557	0.01	0.013798146
	aluminum	b2	5.757143642	0.01	0.005757144
Mass Function	Objective function	z		0.001781019	0.003098726
		f		0.68	0.709909444
Constraints	Objective function	g1		240854.8908	0
		g2		0	-0.000444711
		g3		-0.01	-0.013798146
		g4		-0.01	-0.005757144

해 찾기 모델 설정

목적 셀(E): \$F\$5

해의 조건:  최대값(M)  최소값(m)  지정값(V): 0

값을 바꿀 셀(변수): \$B\$1:\$B\$2

제한 조건(L): \$F\$5:\$F\$5 <= 0

해 찾기 옵션

최대 계산 시간(T): 100 초

최대 계산 횟수(I): 100

정밀도(P): 0.000001

허용 한도(E): 5 %

수렴도(V): 0.0001

선형 모델 가정(M)  단위 자동 설정(U)

변수 아닌 것으로 가정(G)  중간 결과 보기(R)

근사 방법:  1차식(S)  2차식(Q)

미분 계수:  간접(E)  중앙(D)

탐색 방법:  뉴턴법(N)  공역 경사법(Q)

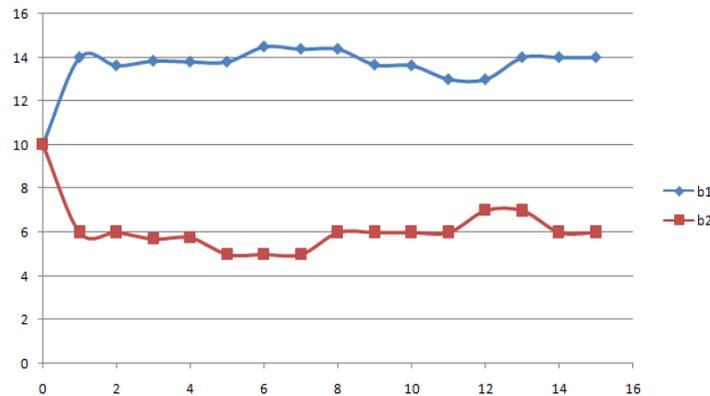
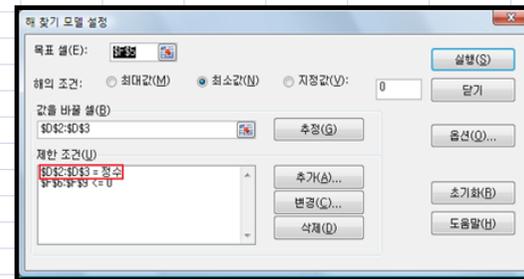
# Comparison

fmincon		genetic algorithm	
b1	14.229mm	b1	14.262mm
b2	5.624mm	b2	5.579mm
function value	0.7232kg	function value	0.7232kg
iteration	10	iteration	6
pattern search		Excel Solver	
b1	14.335mm	b1	13.798mm
b2	5.661mm	b2	5.757mm
function value	0.7284kg	function value	0.7099kg
iteration	5	iteration	5

\* Initial point:  $[10 \ 10]^T$

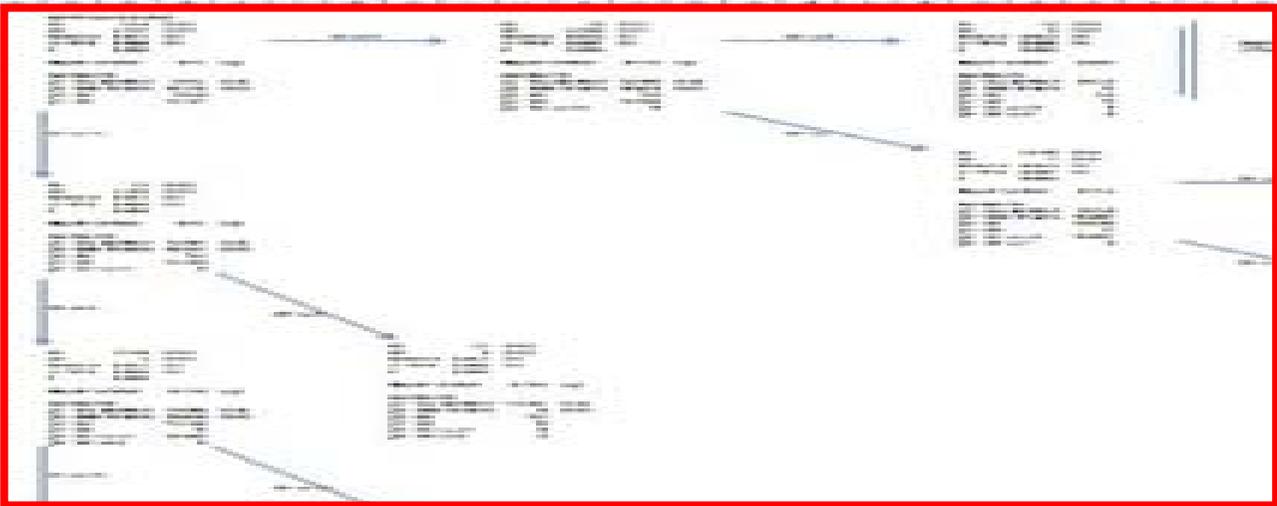
# Solution (Integer)

			[mm]	initial[m]	optimum[m]
Thickness	ceramic	b1	14	0.01	0.014
	aluminum	b2	6	0.01	0.006
Mass Function	Objective function	z		0.001781019	0.003178903
		f		0.68	0.7248
Constraints		g1		240854.8908	-68085.00338
		g2		0	0
		g3		-0.01	-0.014
		g4		-0.01	-0.006

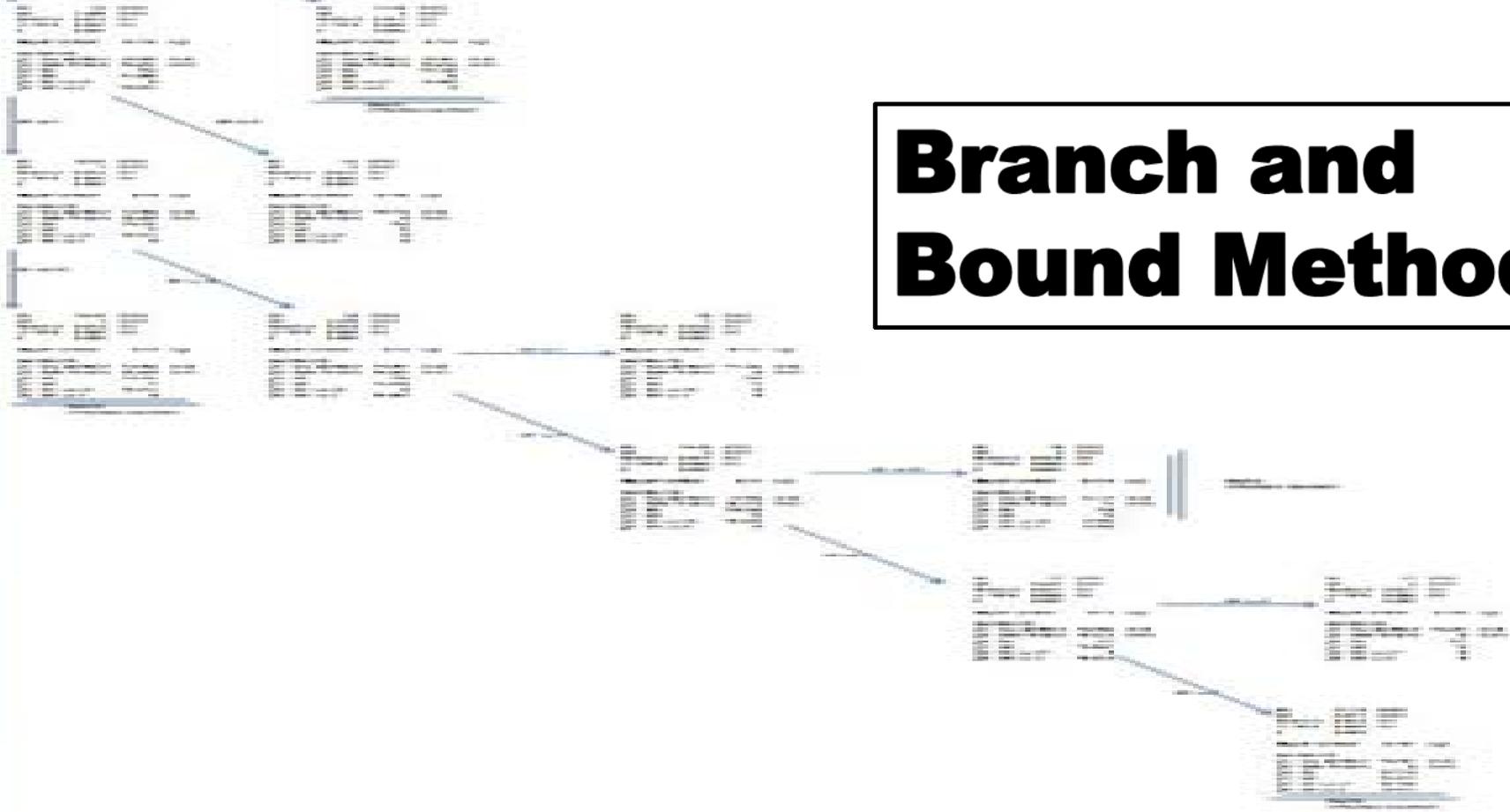


## Excel Solver(int.)

b1	14 mm
b2	6 mm
function value	0.7248 kg



# Branch and Bound Method



# Branch and Bound Method

## Continuous Solution

Ceramic : 13.798mm  
Aluminum : 5.757mm  
function value : 0.7099

$b1 \leq 13$

Ceramic : 13mm  
Aluminum : 6.987mm  
function value : 0.7132

$b1 \geq 14$

Ceramic : 14mm  
Aluminum : 5.482mm  
function value : 0.7101

$b2 \leq 6$

~~Ceramic : 13mm  
Aluminum : 6mm  
 $g1 > 0$   
infeasible solution~~

$b2 \geq 7$

Ceramic : 12.993mm  
Aluminum : 7mm  
function value : 0.7133

$b2 \geq 6$

Ceramic : 14mm  
Aluminum : 6mm  
function value : 0.7248

$b2 \leq 5$

Ceramic : 14.382mm  
Aluminum : 5mm  
function value : 0.7115

**Bound**

• • •

• • •

• • • • •

# Branch and Bound Method

Ceramic : 13mm  
Aluminum : 7mm  
function value : 0.7136

BBM

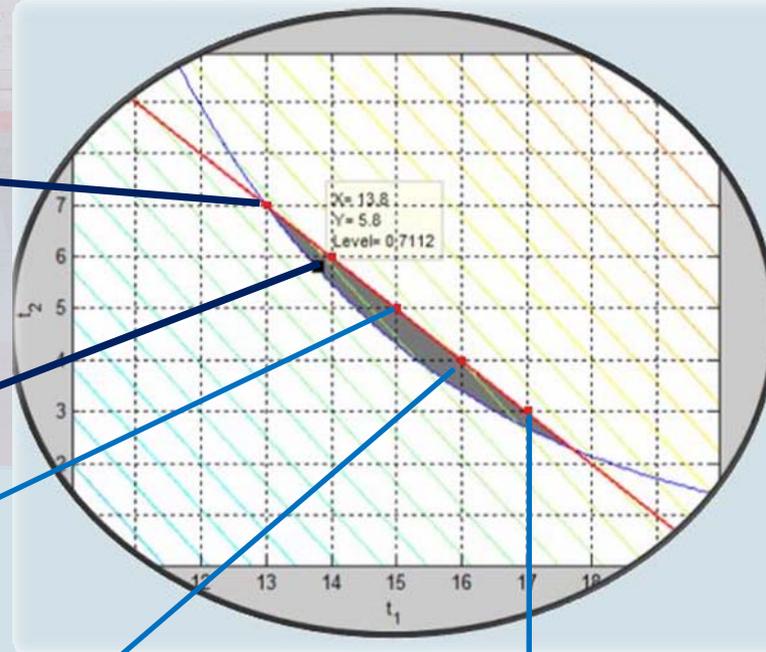
Ceramic : 14mm  
Aluminum : 6mm  
function value : 0.7248

Solver(Integer)

Ceramic : 15mm  
Aluminum : 5mm  
function value : 0.7360

Ceramic : 16mm  
Aluminum : 4mm  
function value : 0.7472

Ceramic : 17mm  
Aluminum : 3mm  
function value : 0.7584

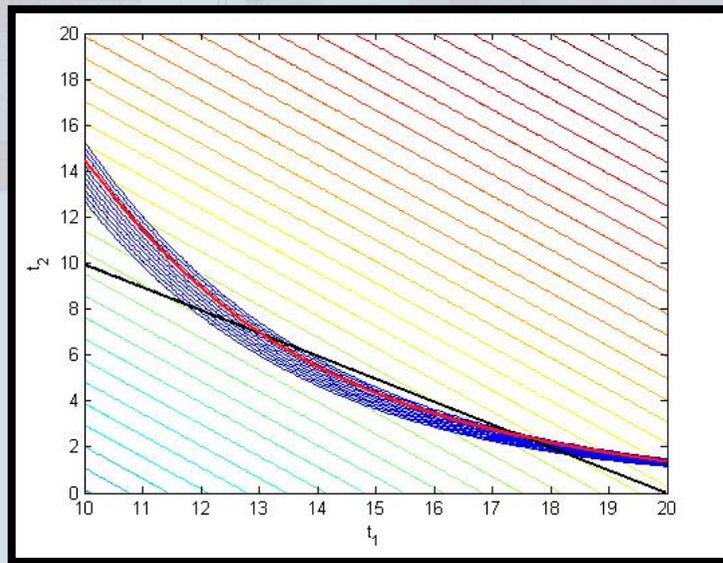


# Conclusion

## A. Continuous Solution

GRG2(Excel solver) vs SQP(MATLAB)

In general, SQP > GRG2 , but ...



### fmincon

function value	0.7232kg
----------------	----------

iteration	10
-----------	----

### Excel Solver

function value	0.7099kg
----------------	----------

iteration	5
-----------	---

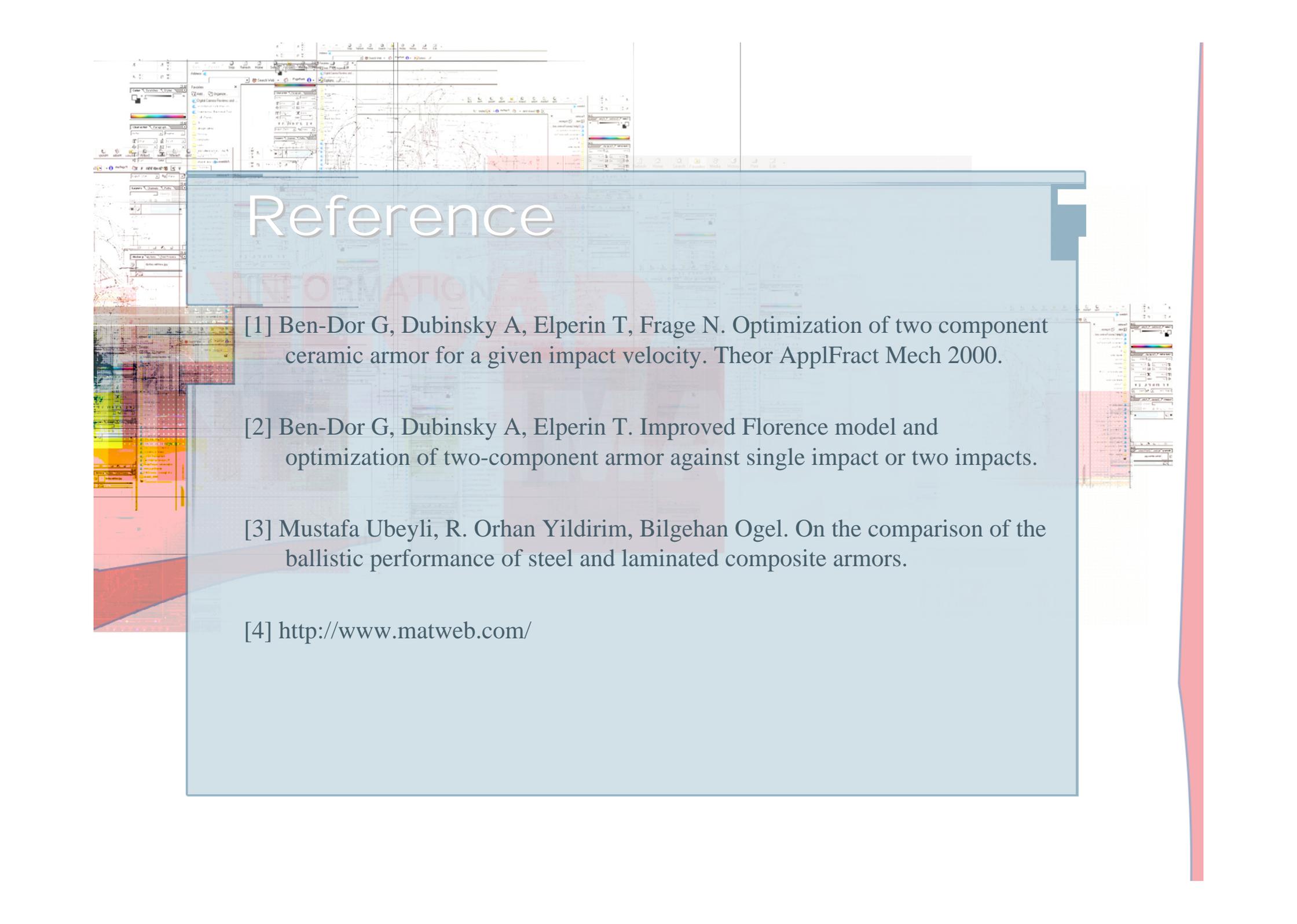
# Conclusion

## B. Integer Solution

Excel Solver(Integer) vs BBM

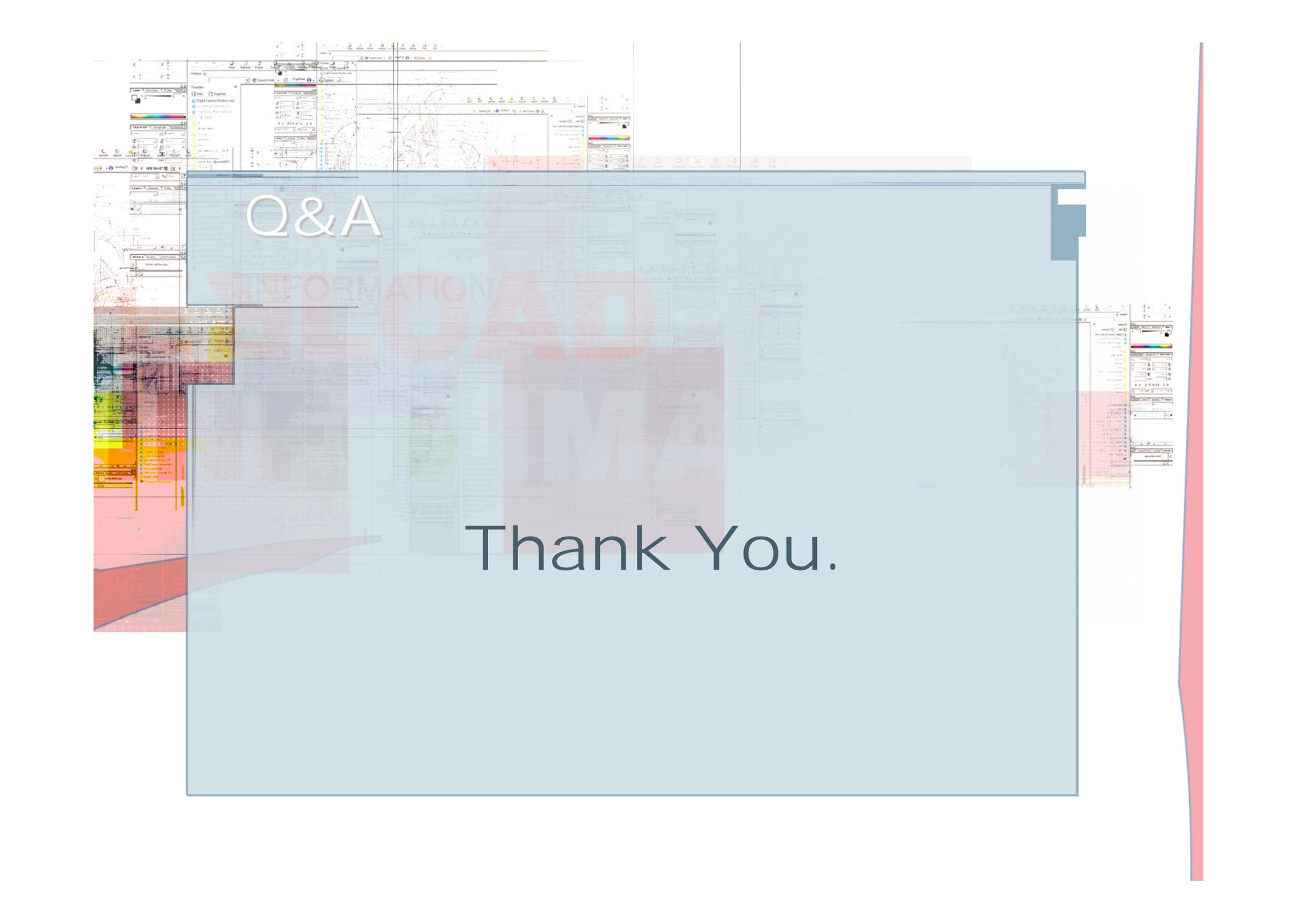
algorithm of Int. solver is based on BBM, but...

Integer Solver		BBM	
b1	14mm	b1	13mm
b2	6mm	b2	7mm
function value	0.7248kg	function value	0.7136kg
iteration	15	iteration	21



# Reference

- [1] Ben-Dor G, Dubinsky A, Elperin T, Frage N. Optimization of two component ceramic armor for a given impact velocity. Theor Appl Fract Mech 2000.
- [2] Ben-Dor G, Dubinsky A, Elperin T. Improved Florence model and optimization of two-component armor against single impact or two impacts.
- [3] Mustafa Ubeyli, R. Orhan Yildirim, Bilgehan Ogel. On the comparison of the ballistic performance of steel and laminated composite armors.
- [4] <http://www.matweb.com/>



Q&A

Thank You.