Knowledge-based rapid prototyping

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Rapid Technologies

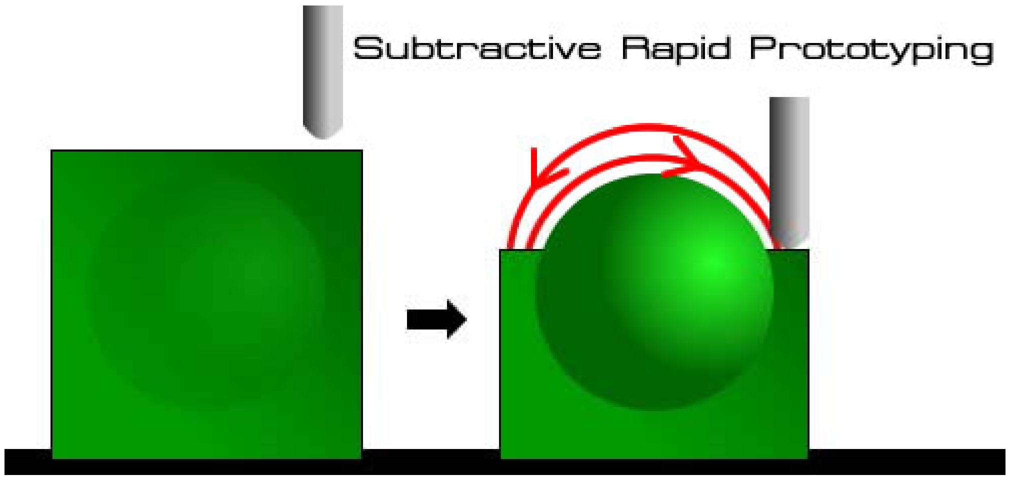
- Rapid technologies (RTs) are solutions that enable us to fulfil shape-intensive manufacturing expectations:
  - Reduce costs while increasing speed and accuracy
  - Physical realisation of products well before full-scale manufacturing
  - Improve quality

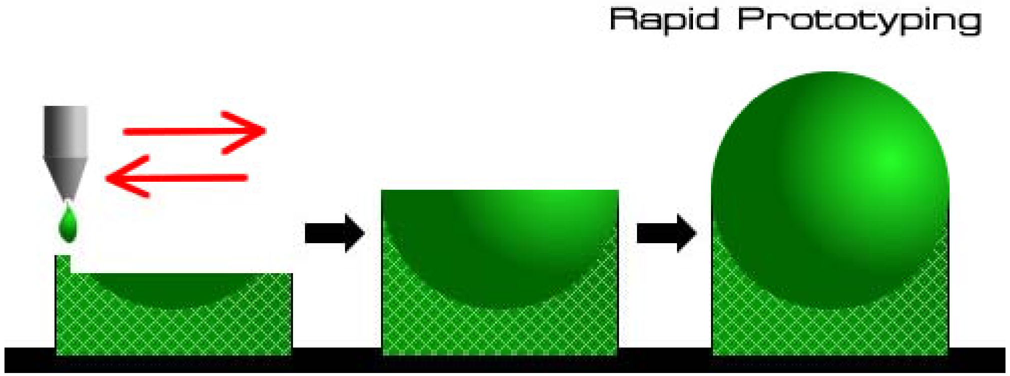
- **Two basic characteristics of RTs:**
  - Independence from the shape of the object to be manufactured
  - Dependence on physical principles, materials and target applications

Quin Lamp

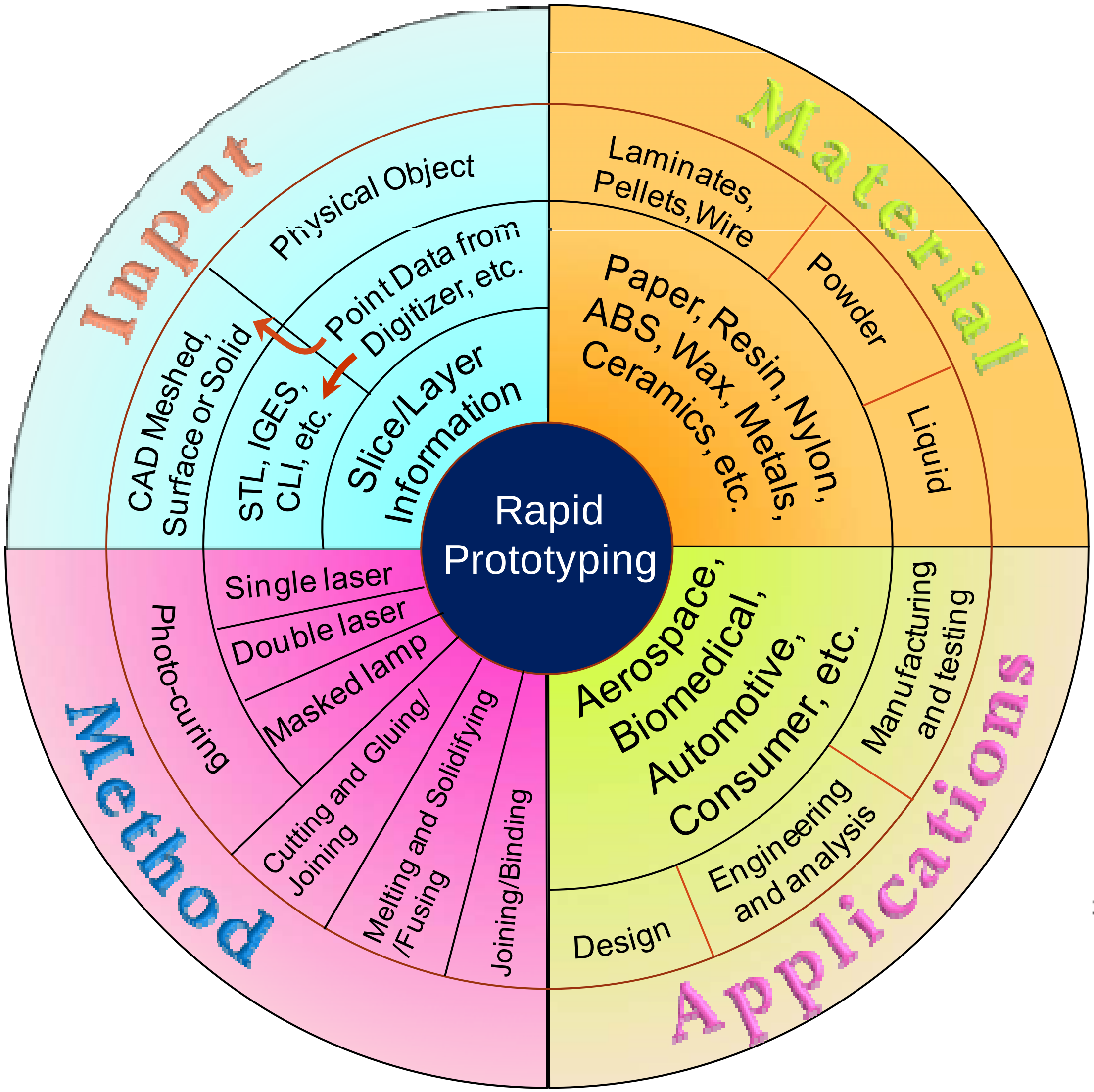
Photo courtesy Bathsheba Grossman

Categories of Rapid Technologies

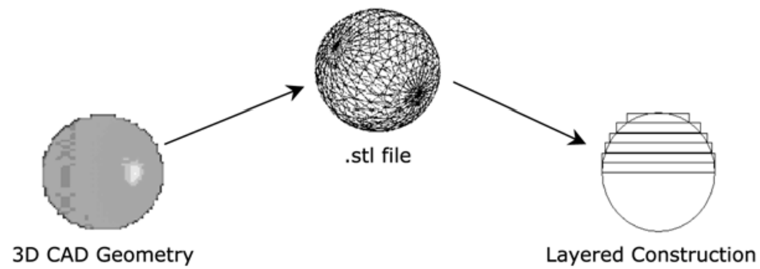




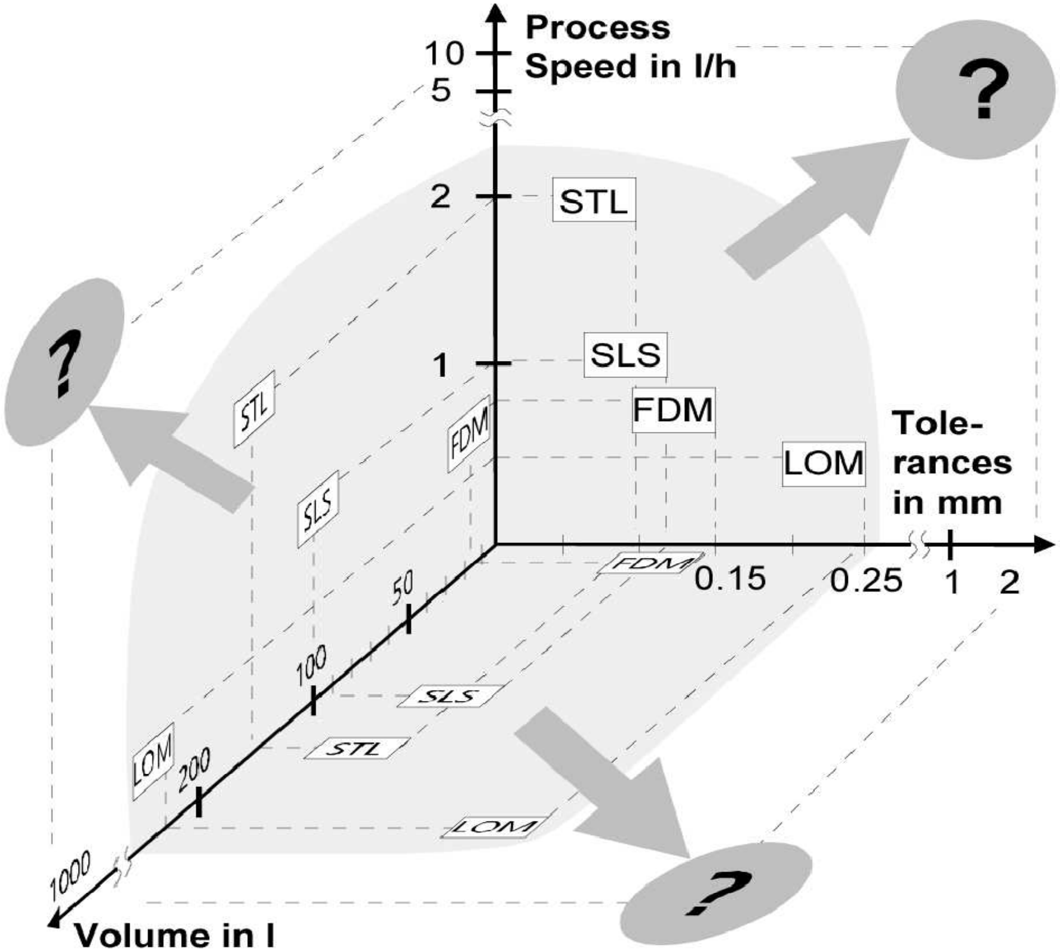
Rapid prototyping fundamentals



- Input
  - 3D model
  - Scanned data
    - CMM
    - Laser
    - CT



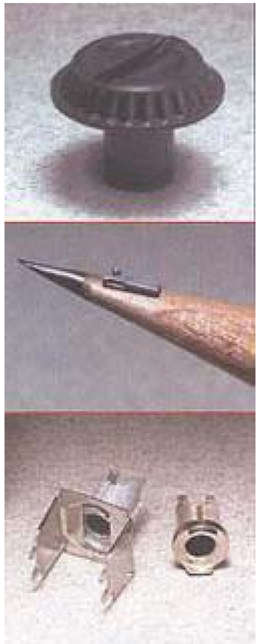
RP Capabilities and Applications



Legend:

STL	Stereolithography
SLS	Selective Laser Sintering
LOM	Laminated Object Manufacturing
FDM	Fused Deposition Modelling

Volume scale unit:
1 l = 1 Litre = 10^{-3} m^3



Design freedom

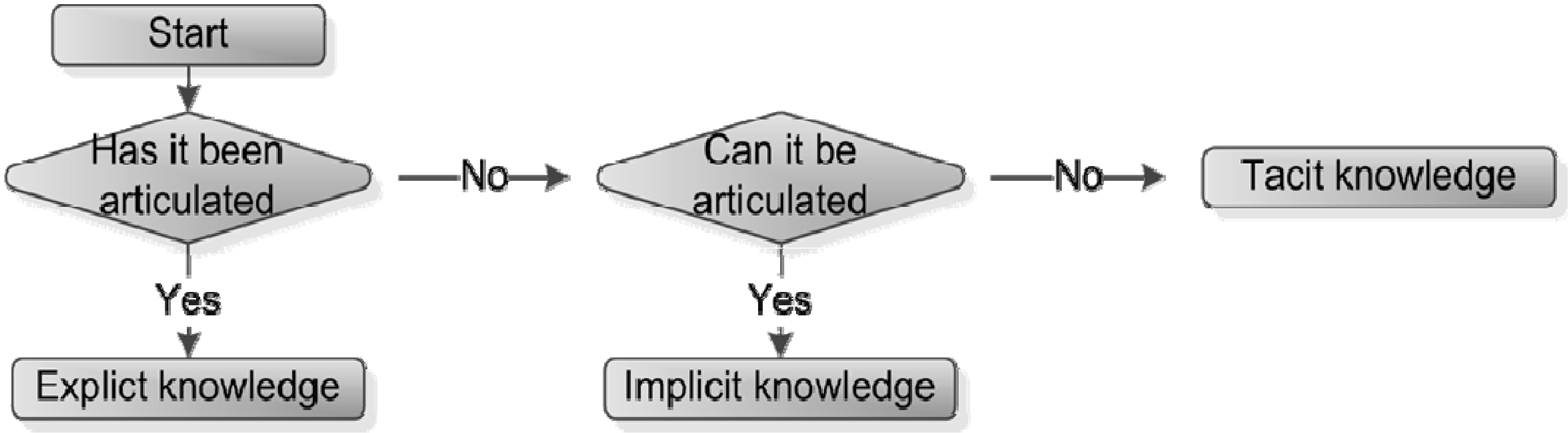
Diverse range of RTs supports:

– Significant design freedom based on their ability selectively to remove, deposit or form materials

Scientific engineering knowledge

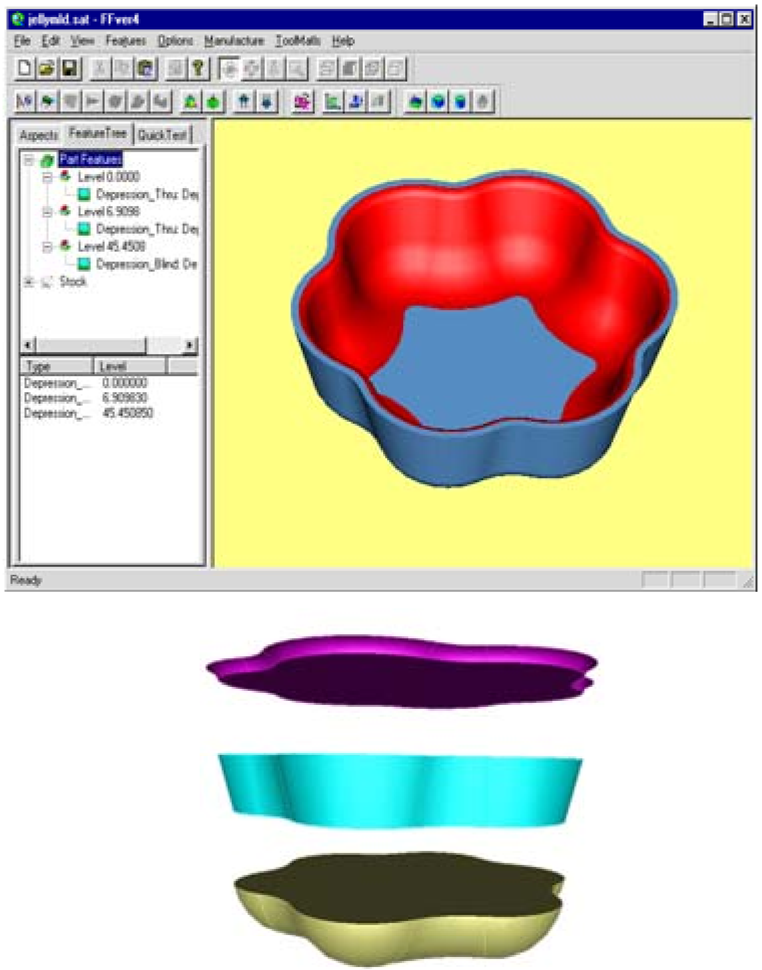
- Manufacturing is moving form resource-based to knowledge-based
- Knowledge content of manufactured products about 5% in 1945
- Today it's about 16%
- EU target by 2020 - at least 20%.

Knowledge advantage



- To optimize specific production resources and processes;
- Transfer captured knowledge via knowledge platforms and competence networks to other areas where it can be employed to advantage.
- Knowledge as a ‘product’ is becoming more important to many SMEs constituting the great majority of the manufacturing enterprise pool.

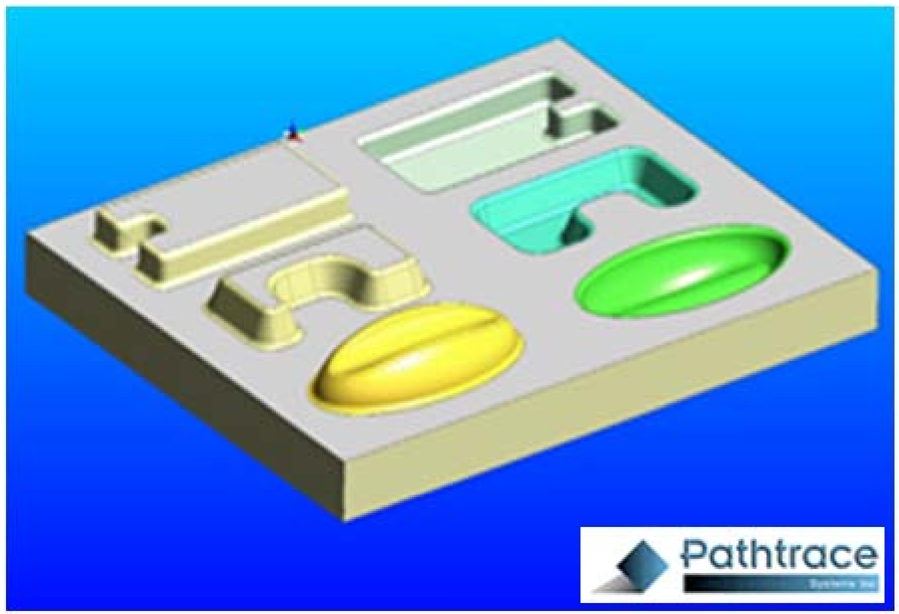
HWU Manufacturing Feature Finder



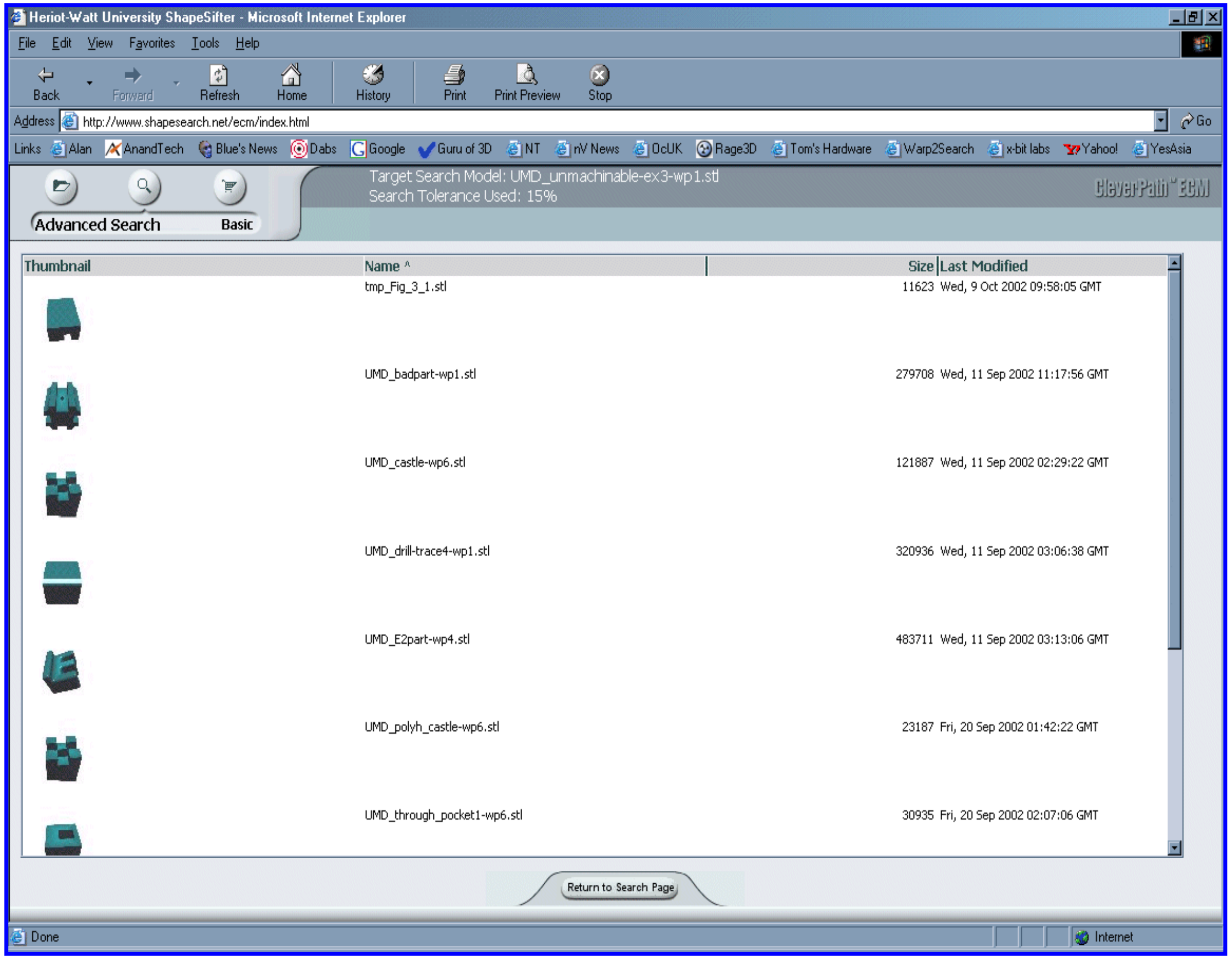
Heriot-Watt Feature Finder

Automatic feature finding

EdgeCAM Solid Machinist uses automatic feature recognition to interrogate the solid model to find machinable features. This information is then used to select the correct tools and to machine the features using EdgeCAM's extensive range of cutting strategies.

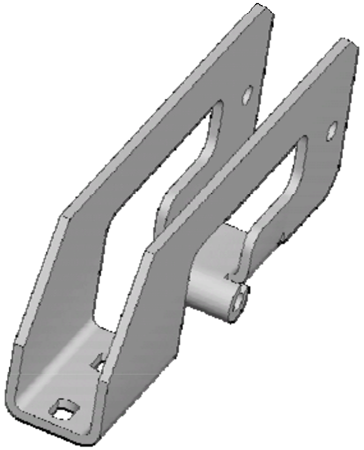


3D Part Search Engine

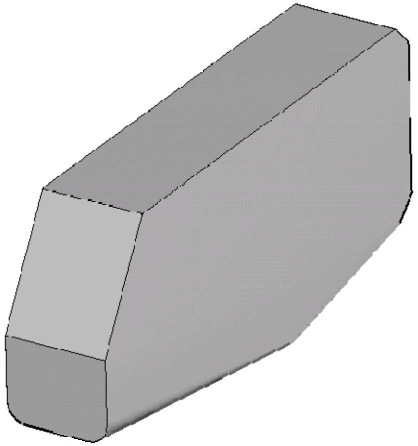


http://www.partbrowser.com/

3D search engine



Model



Convex Hull

Model Searching Parameters

Parameter	Formula	Search tolerance
Hull Crumpliness	$Hcp = \frac{A_{mod}}{A_{Hull}}$	10%
Hull Packing	$Hp = 1 - \frac{V_{mod}}{V_{Hull}}$	50%
Hull Compactness	$Hc = \frac{A_{Hull}^{3}}{V_{Hull}^{2}}$	25%

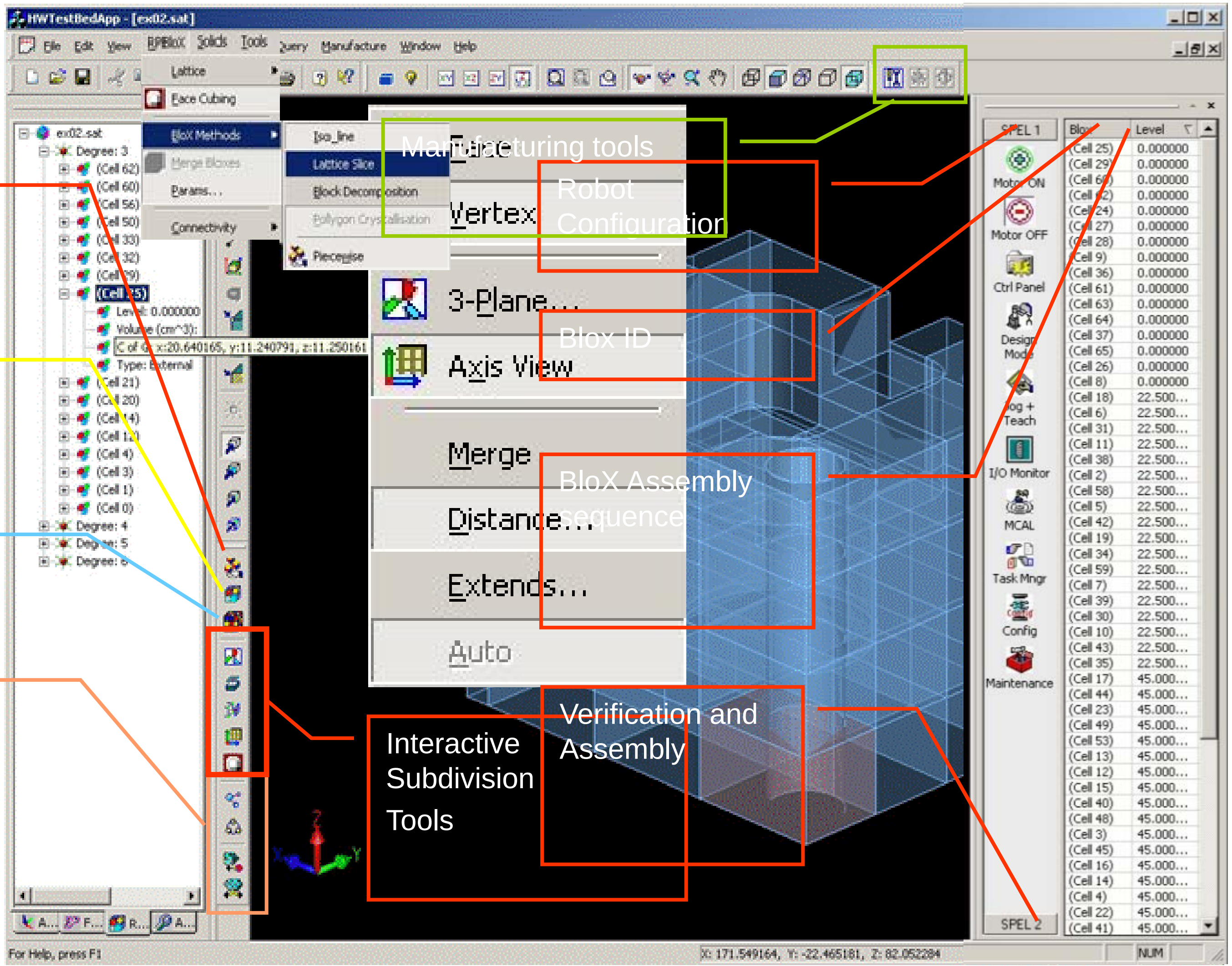
RPBloX TestBed

Piecewise operator

Blox Methods

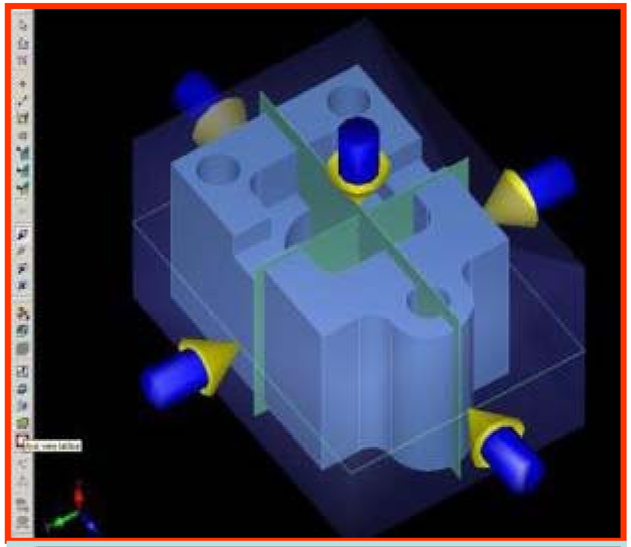
Merge operator

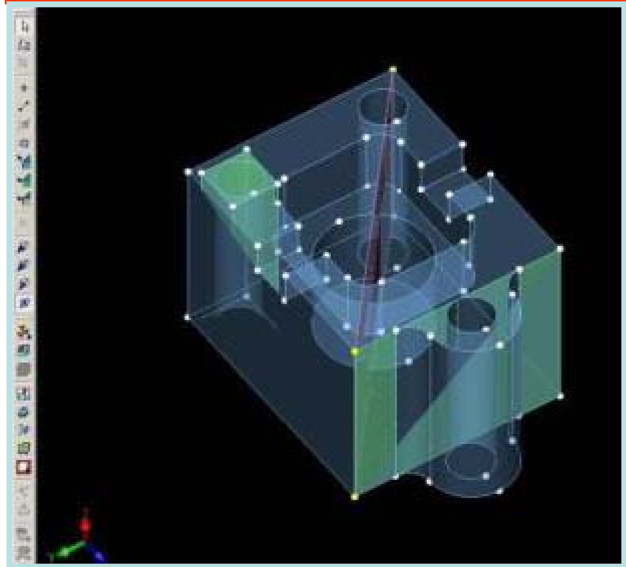
Cell operators



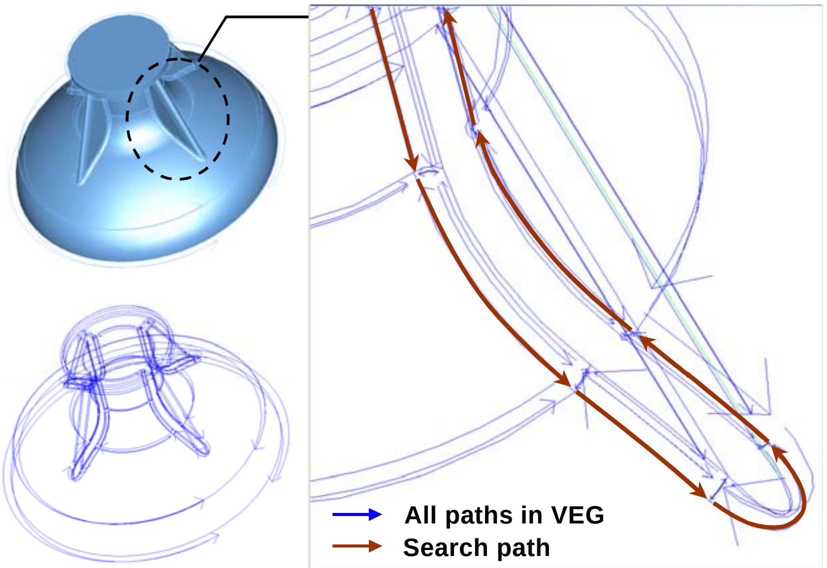
Subdivision Methods

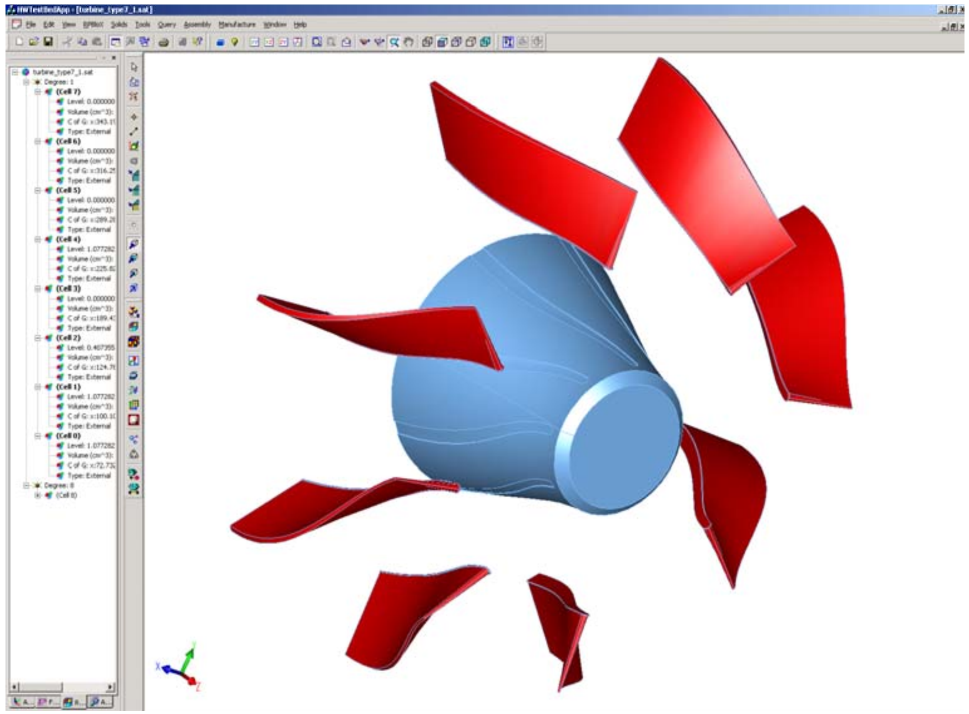
- Manual (Interactive)
- Uniform (Slicing Lattice)
- Block Decomposition (Face-bounding)
- Loop-based Decomposition
- Isoline Decomposition
- Pattern Decomposition





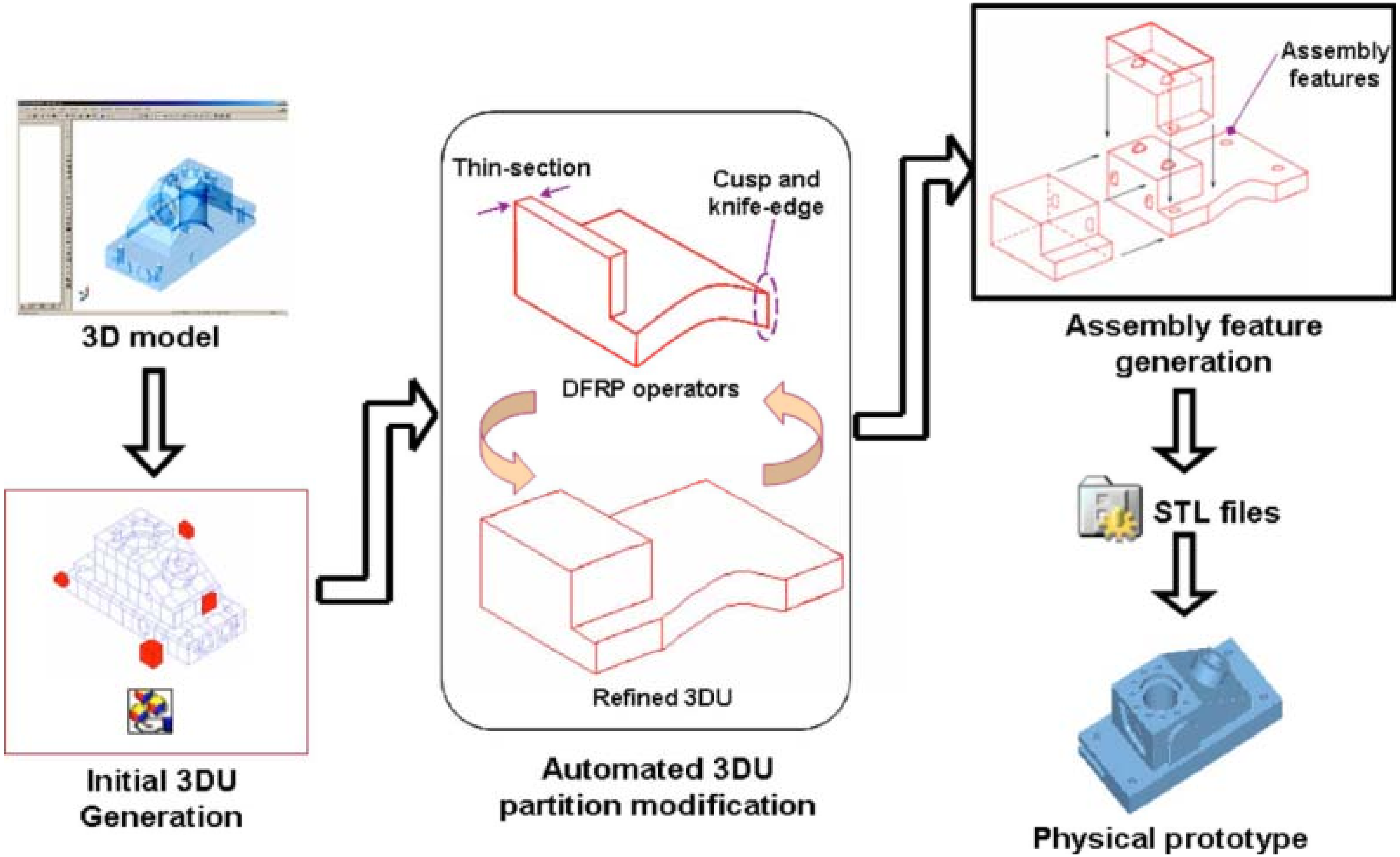
Subdivision of Freeform Solids using feature knowledge





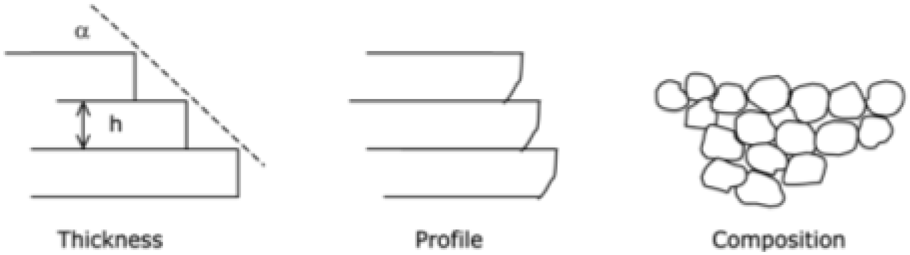
Model decomposition and Feature Recognition

Design for Manufacture and Assembly (DFMA)

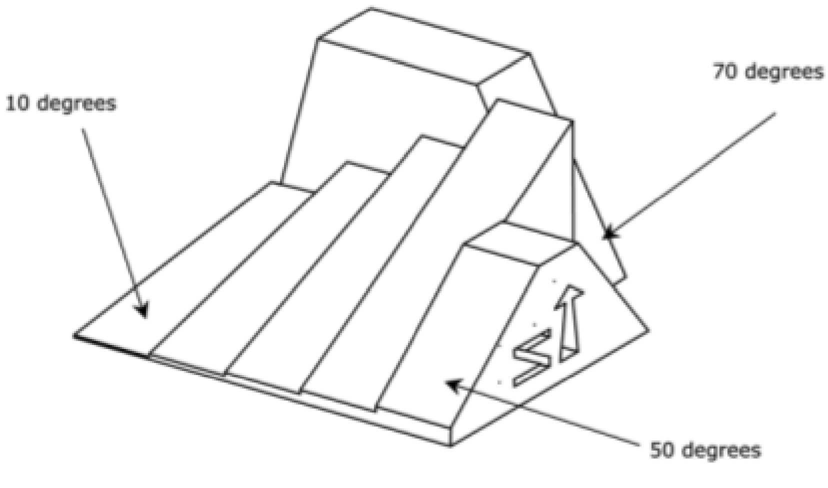


DFMA (RP Part Orientation)

- Surface roughness
- Dimensional accuracy
- Mechanical properties



Factors that affect the surface roughness of RP parts



RP surface roughness measurement test piece

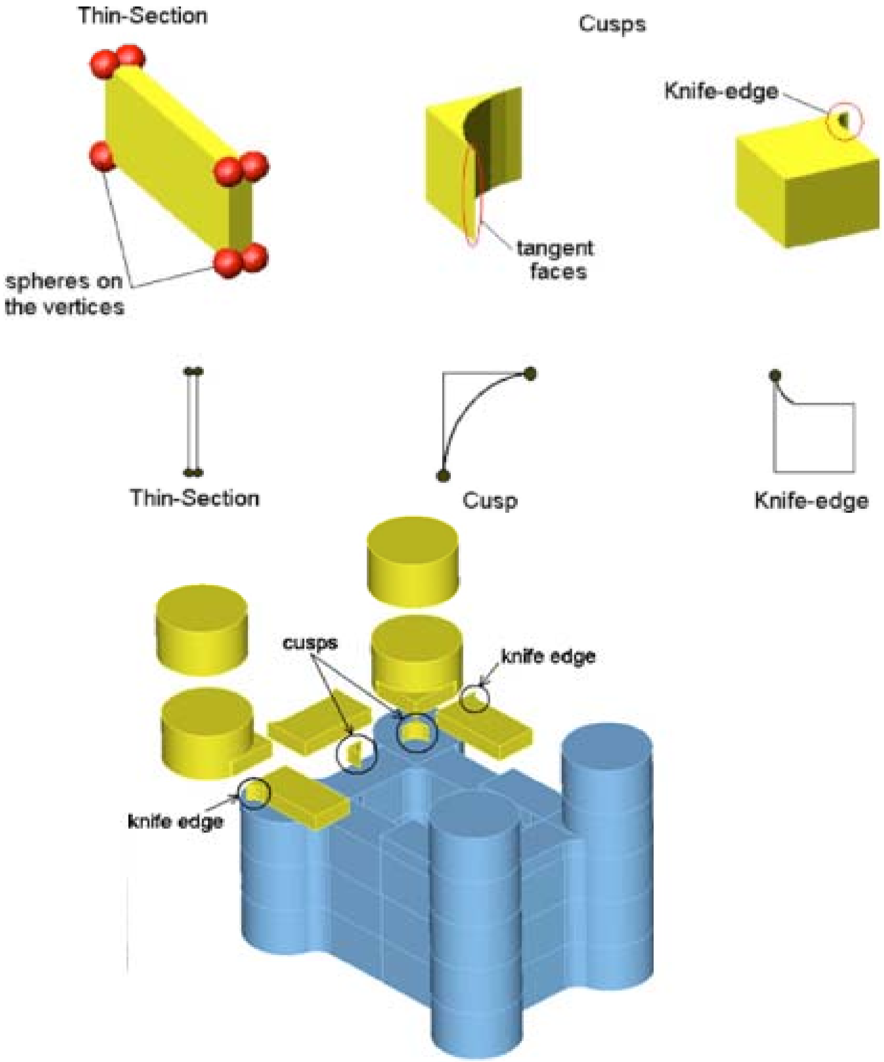
Technology – material	Layer thickness	Build angle, α/degrees 10	30	50	70	90
SLA – Epoxy (ACES style)	0.15	39.9	28.8	21.5	16.7	6.3
SLS – Polystyrene	0.20	65.2	35.6	32.6	24.7	20.6
SLS – Nylon	0.10	28.5	36.9	36.5	39.2	11.8
LOM – Paper	0.10	29.2	27.7	25.3	23.3	16.9
FDM – ABS	0.25	56.6	38.6	26.4	22.7	17.9

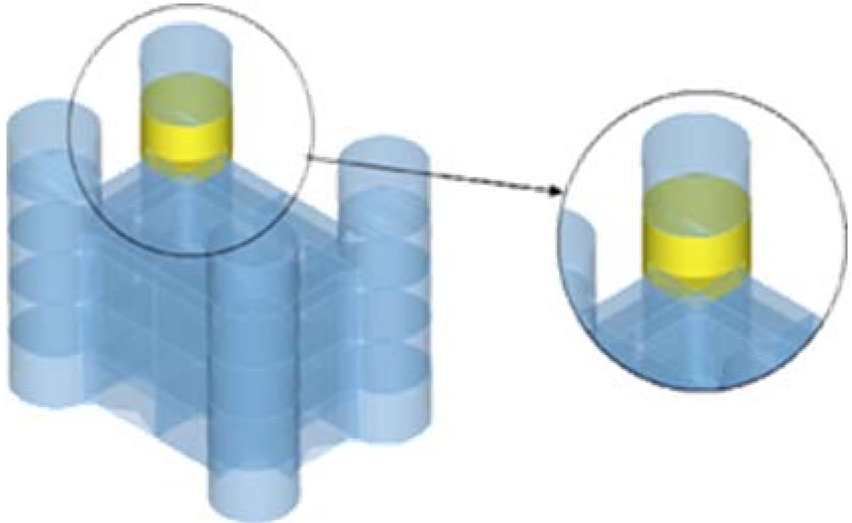
Surface roughness (µm Ra) for selected RP technologies

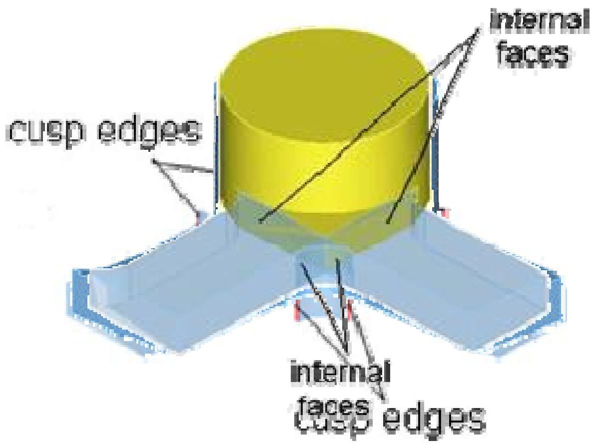
Technology – material	Intended dimensions from CAD model (mm) 34.50	50.35	52.50	56.00	60.00	71.00	75.00
	Actual dimensions of test parts (mm)						
SLA – Epoxy (ACES)	34.83	50.57	52.77	55.85	59.97	70.97	74.94
SLS – Polystyrene	34.43	50.45	52.62	56.48	60.14	71.31	75.12
SLS – Nylon	34.77	50.37	52.59	55.99	60.39	70.65	74.99
LOM – Paper	34.67	50.61	53.20	55.98	59.92	71.05	74.86
FDM – ABS	34.38	50.07	53.45	55.46	60.09	70.42	75.08

Linear dimensional accuracy of different RP technologies

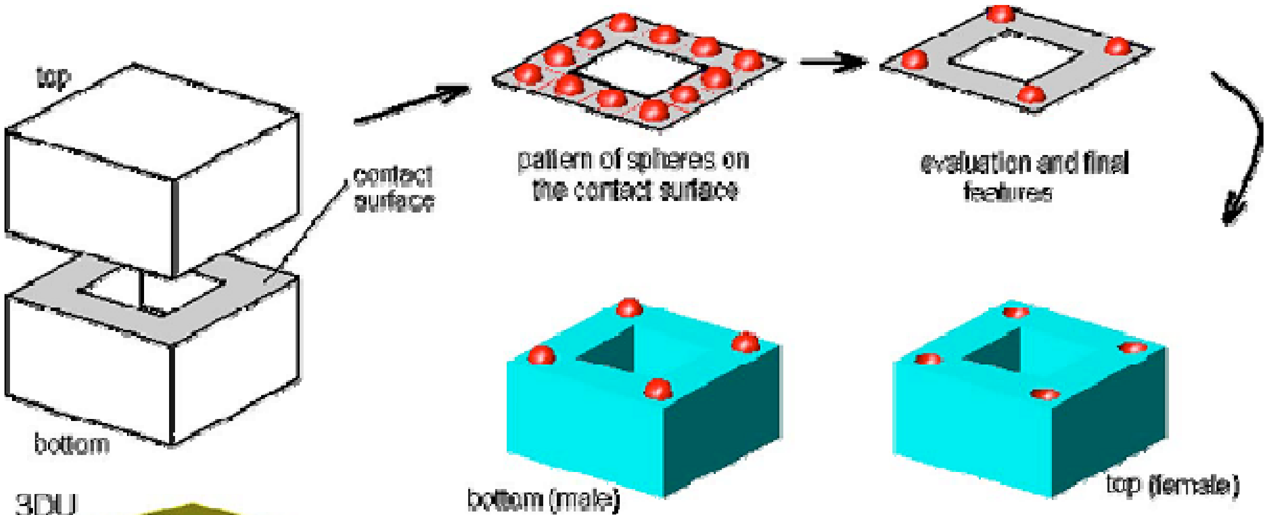
DFMA (Manufacture)

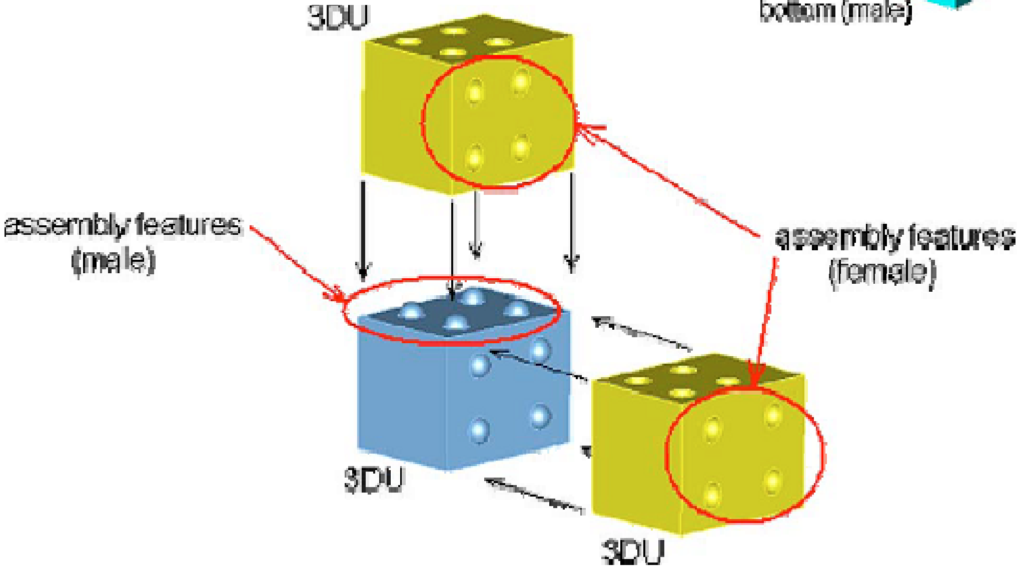


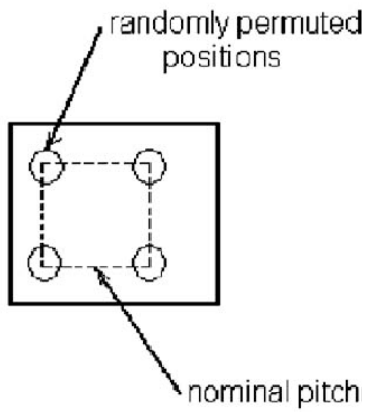




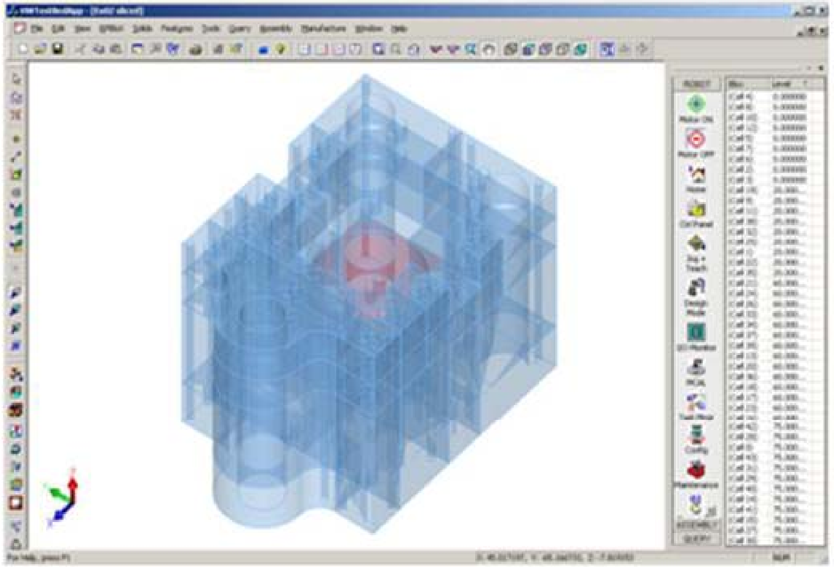
DFMA (Assembly)

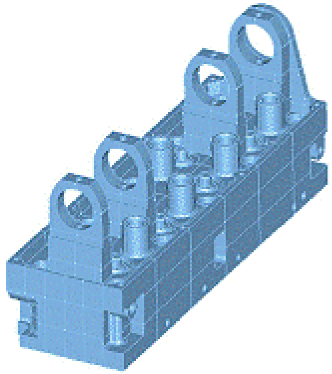


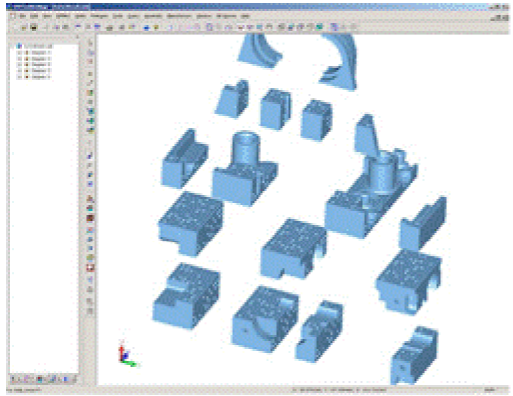


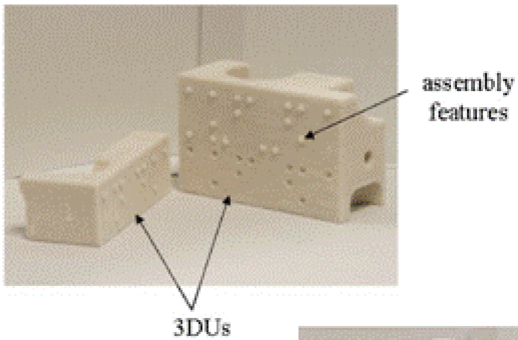


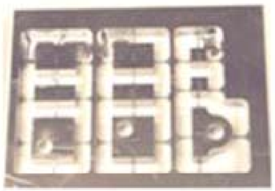
DFMA RPBloX - 3D Model in, Jigsaw out

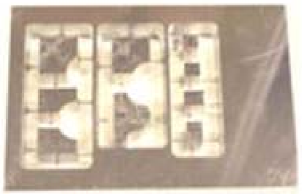


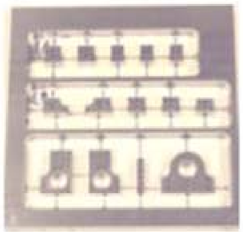


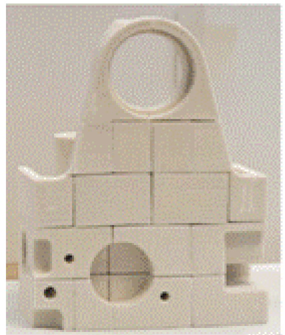












James Watt Institute for High Value Manufacturing

Virtual Assembly and Rapid Prototyping

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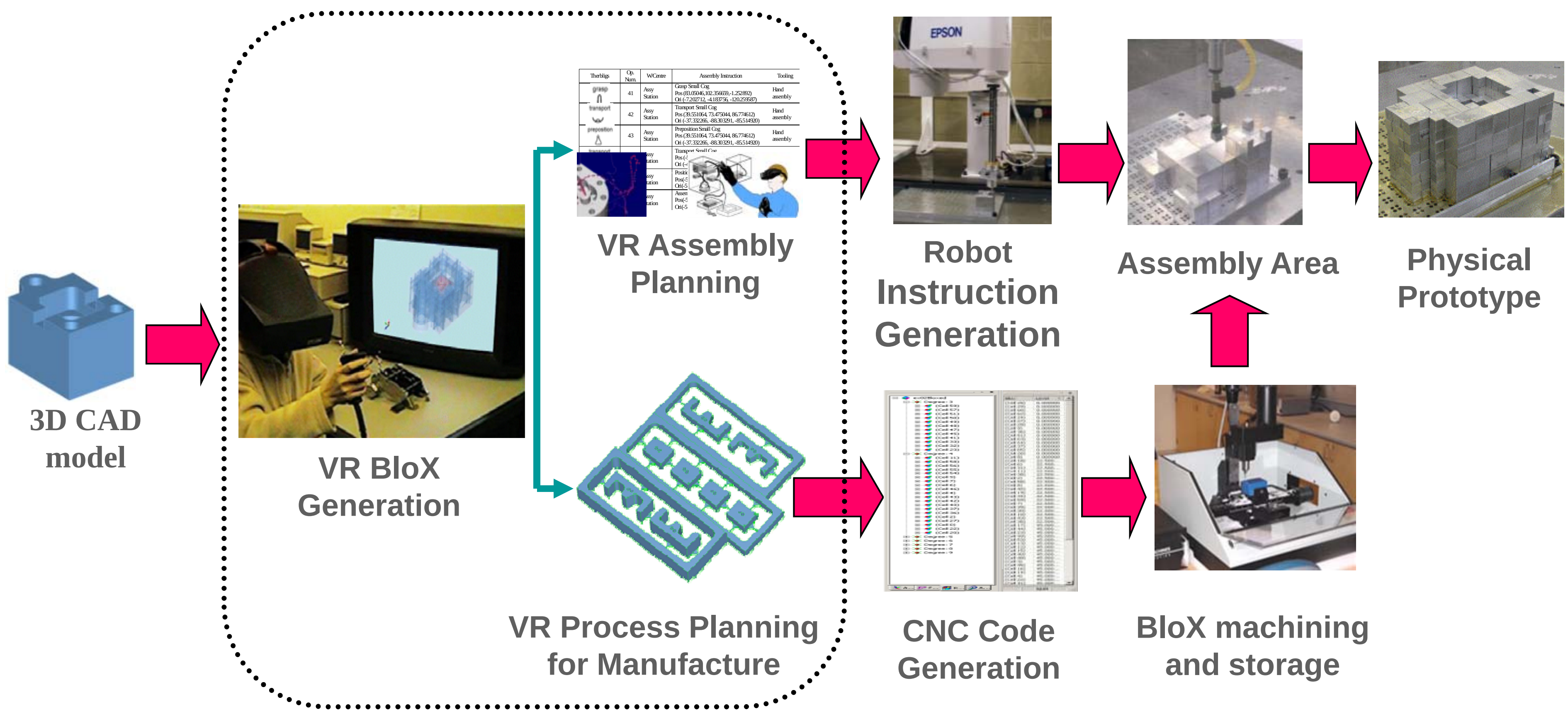
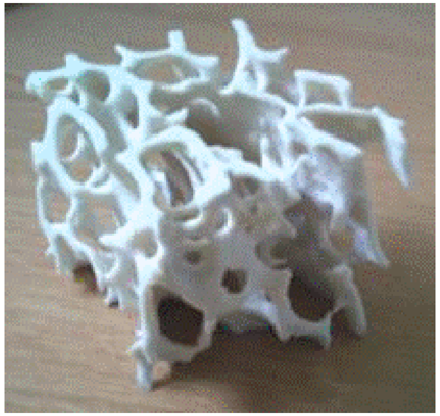
VARP Interface



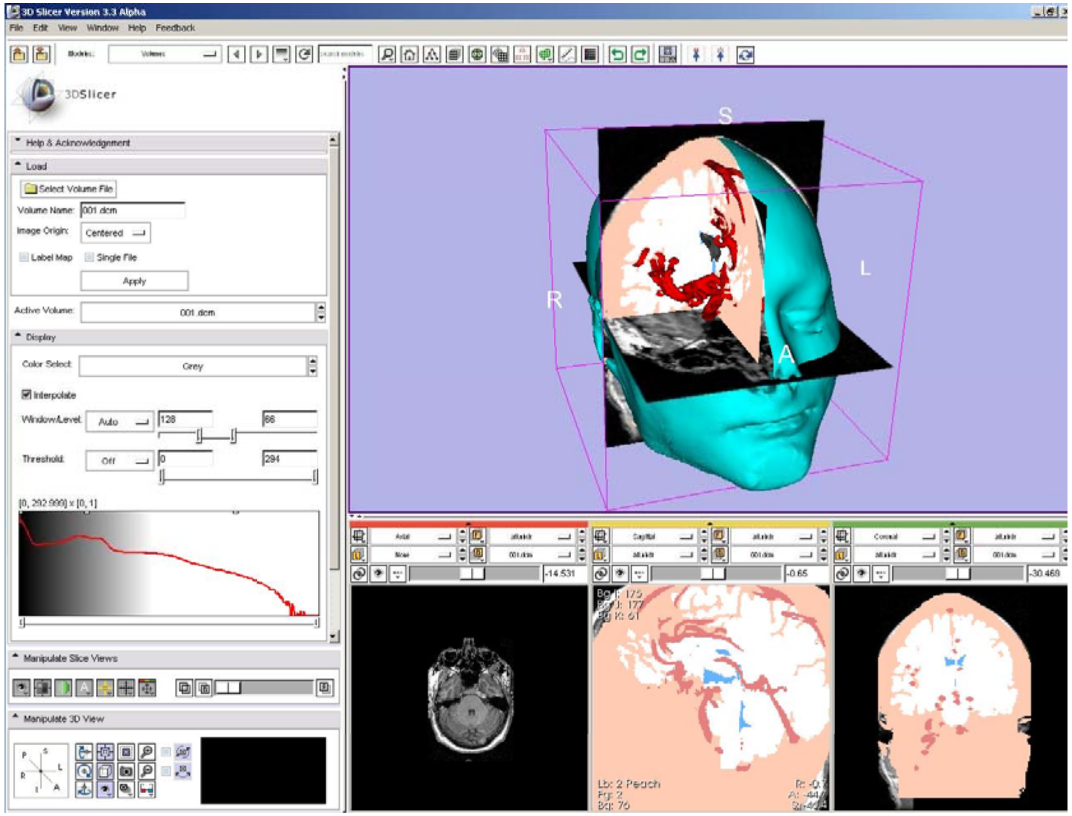
RP Support for Medical Applications

- RP-based fabrication has been used in the following medical applications:
  - ➢ Surgical and diagnostic aids
  - ➢ Prosthetics and medical product development
  - ➢ Manufacturing
  - ➢ Tissue Engineering

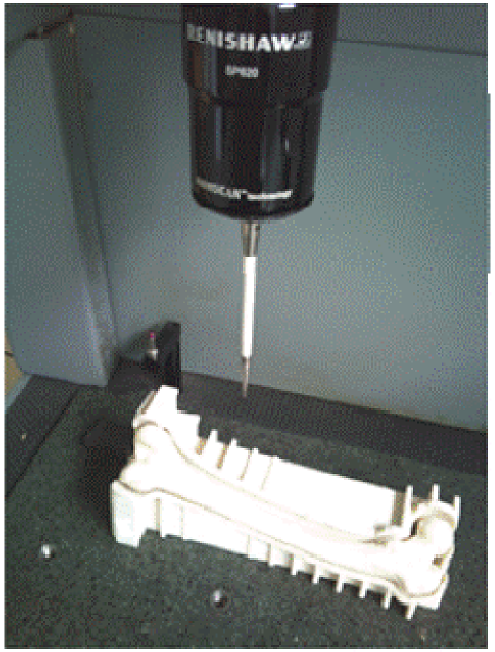


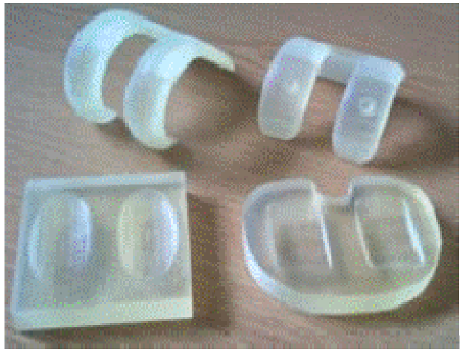
Due to the complex, organic nature of the product, RP technology was the most effective means of realizing these models.

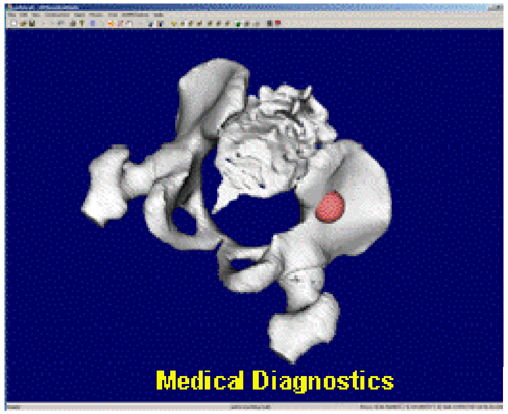
Surgical and diagnostic aids

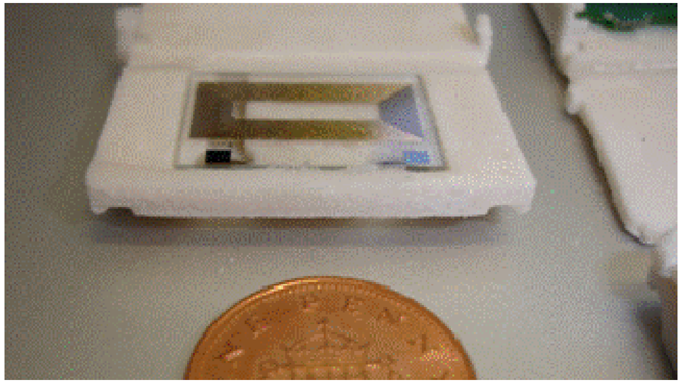


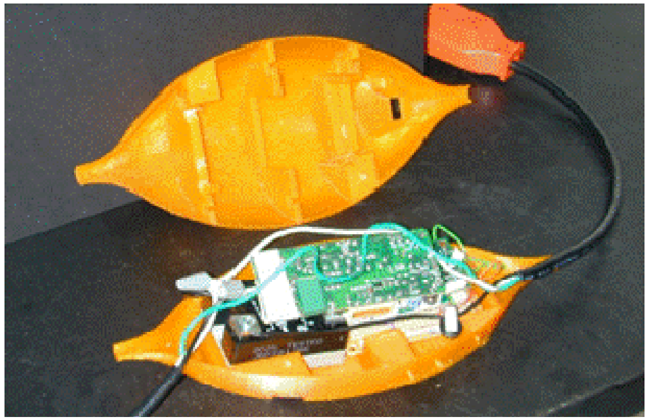
RP Validation







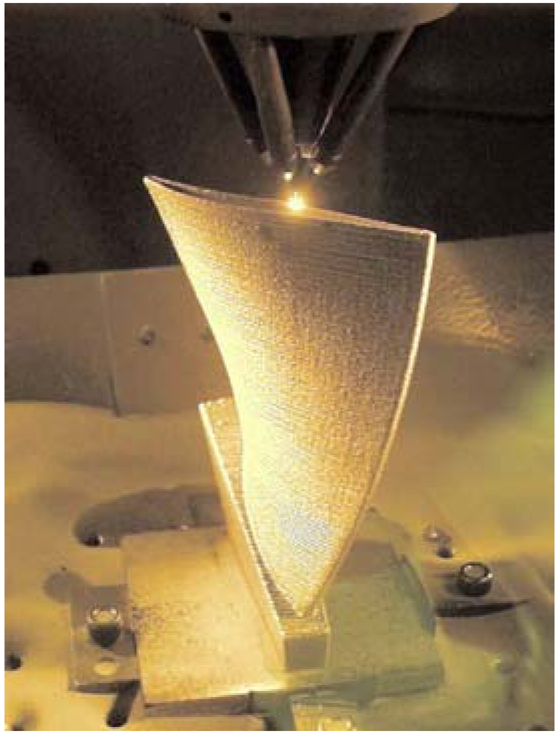




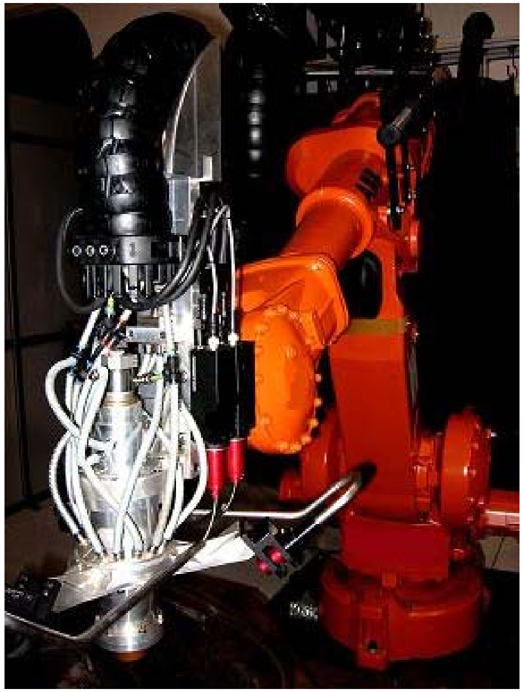
RT S-O-A

Direct AIM™

DSM Somos® NanoTool™



Laser Engineering Net Shaping (LENS)



Direct Metal Deposition ™ (DMD)

Limitations of RP

- ***Speed***: *RP models can take a day or even longer to create.*
- ***Cost***: *Using RP models to solve manufacturing problems is economical in high-volume productions.*
- ***Accuracy***: *Very high precision RP is still not available.*
- ***Materials***: *Only a few RP materials are classified as safe for transport into the operating room and none are currently safe for insertion inside the body.*
- ***Ease of Use***: *RP machines generally require a degree of technical expertise to achieve good quality models.*

CONCLUSION

- A dominant technology for producing physical models for testing and evaluation purposes has been RP.
- Traps
  - Trial & Error may replace analysis
  - Design-for-Manufacturing may be overlooked
- Application of design and knowledge engineering in RP enables better manufacturability and dis/assemblability.
- Most of the problems regarding industry acceptance to RP are procedural rather than technical issues.
- A concerted effort to convince/educate industry of the value that RP offers will advance their usage.
- R&D related to RTs can be viewed in terms of four interconnected fields: processes, materials, machines and controls.