ME 482 – Rapid Product Development and Manufacturing

Chapter 6

Rapid Manufacturing (Part III)

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Rapid Manufacturing Applications

- One of the greatest benefits of Rapid Manufacturing (RM) is that it enables the economically viable production of a product in which all the design features are in direct response to a given application.
- There are minimised compromises imposed on the design by the limits of the production process or the necessity to produce goods that are of a *'best fit'* such as with mass production.
- Such capabilities will allow the viable manufacture of one-off products that are custom-made in respect of shape and functionality. Each of our bodies are different, thus providing a wide area of applications for custom-made products.
- Thus, Rapid Manufacturing techniques have been widely preferred in many fields such as *medical treatment, healthcare, hearing, automotive, aeronautical, space, construction* and *retail industries*.

Pre-Surgery Rapid Manufacturing

- Some of the earliest medical applications of layer manufacturing and associated technologies have been exploited in pre-surgical activities.
- In several applications the object manufactured is directly utilised to produce a desired 'end product', *i.e. surgical simulation.*
- High-complexity surgical procedures can have a duration in excess of 10 hours. The longer this period, the greater the risk to the patient. Thus, any planning, practice, simulation, evaluation and decision making that can be performed pre-surgery is of great value.
- Surgical planning tools represent some of the earliest examples of RM in healthcare applications.

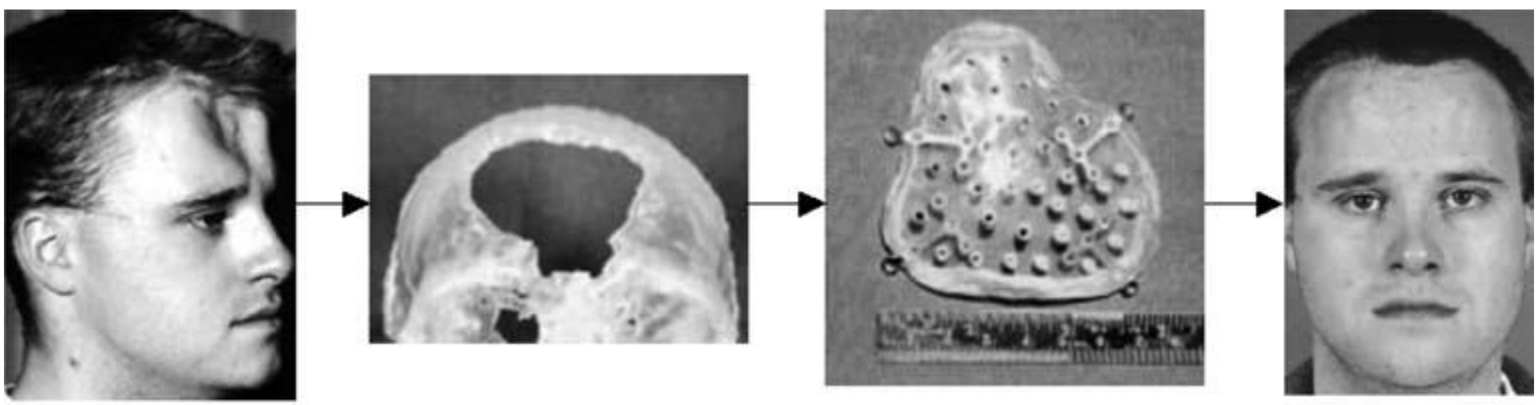
Pre-Surgery Rapid Manufacturing

- Applications are normally dependent on X-ray computer tomograph (CT) or magnetic resonance imaging (MRI) patient data and include:
  - Pre-operative planning
  - Pre-forming of fixation components
  - Manufacture of surgical guides and templates
  - Simulation of surgical procedures
  - Fit evaluation of implants
  - Patient demonstration
  - Intraoperative guidance
  - Surgeon training and tangible recording

Medical Applications

Pre-Surgery Rapid Manufacturing

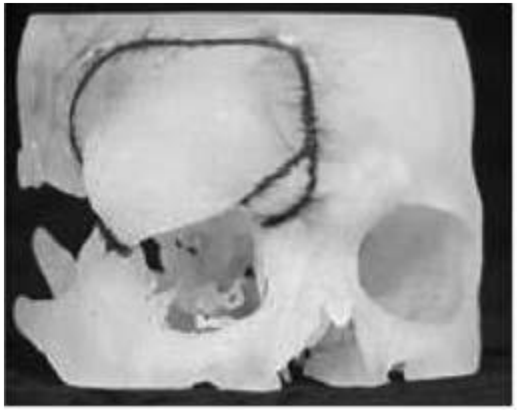
- A large craniofacial traumatic frontal bone defect. Both protective and cosmetic reasons made reconstruction of this defect necessary.
- A cranioplasty implant was indirectly produced via a SL model of the damaged area. Subsequently, precise fitment of the implant shortened the operation time and eliminated the need for any corrections.



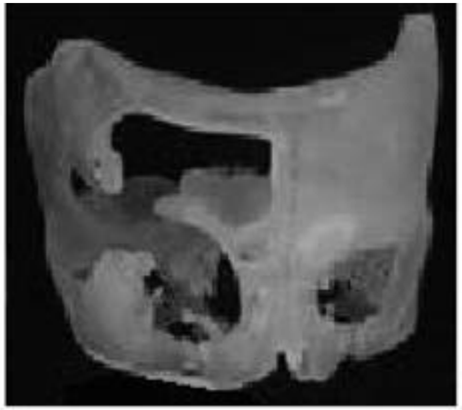
Patient pre-op | RM of damaged area | PMMA implant | patient post-op

Pre-Surgery Rapid Manufacturing

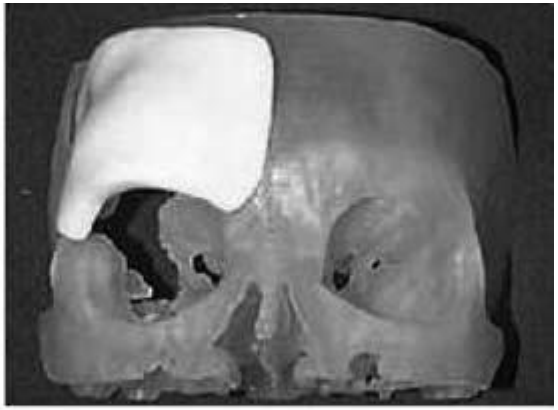
- A large right frontal bony growth which was removed. The patient subsequently exhibited a reduced orbital volume and distinct cosmetic deformity.
- The proposed subtractive surgery was initially simulated utilising BioModels of the patient's cranial geometry. Post-surgery, another BioModel was generated from which an implant was modelled, produced and evaluated.



Model pre-op



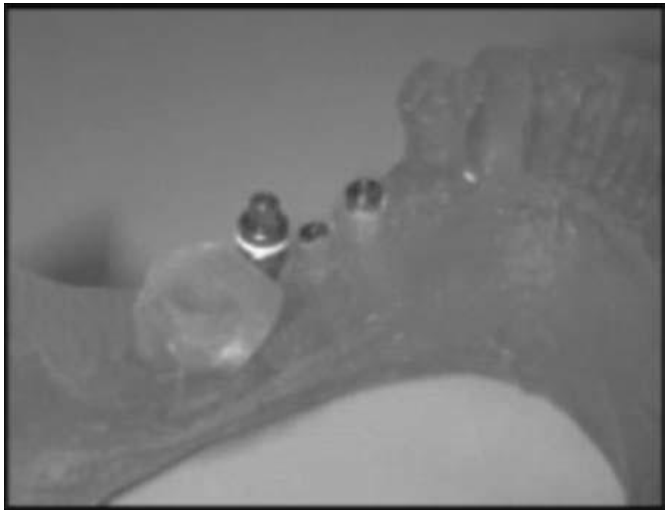
Model post-op

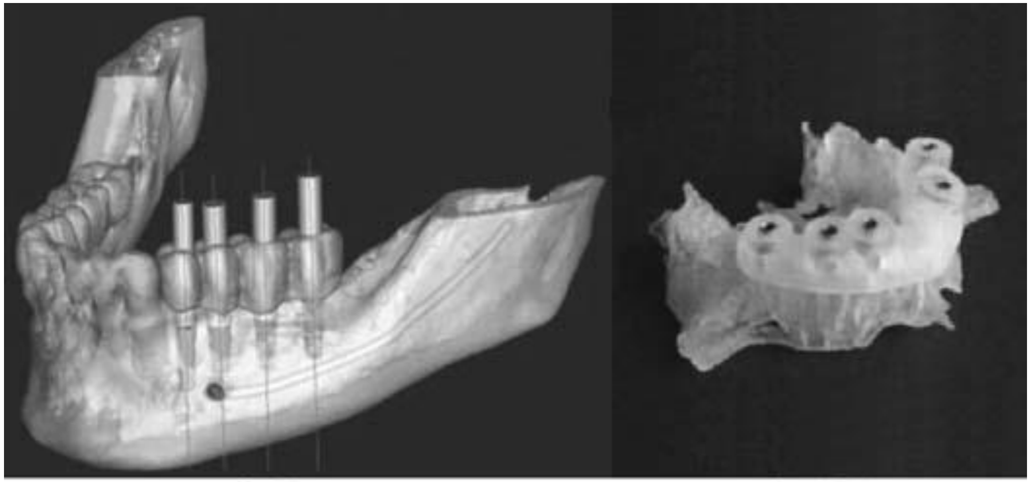


Model & resection template

Orthodontics

- The use of RM has been heavily utilised in orthodontics, in particular for oral implantation.
- The drilling of relatively long holes into such narrow bone structures at a precise position requires great accuracy and when conducted manually is prone to error. Reverse engineering and RM have been utilised to allow the production of assisting tools and guides that provide improved accuracy, greater treatment speed and virtually zero risk of misplacement





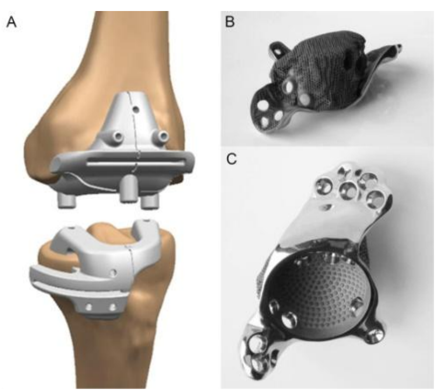
SimPlant SurgiGuide

Limb Prosthesis

- Each of our bodies vary in their geometry and so create many demands for custom-made products. In the case of prosthetic limbs, damaged areas become interfaces between the body and the prosthetic. The fit at this interface is especially critical due to the need for accurate mechanical load transfer and comfort.
- The need for customised products is further emphasised by the frequent revisions required due to the changing geometry of the damaged limb. There have been several examples of research efforts in RM for limb prosthesis.

In Vivo Devices

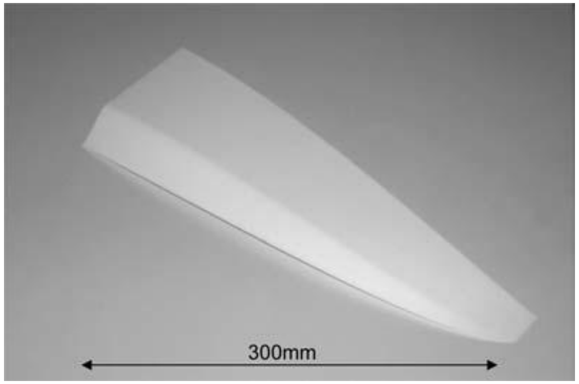
- In vivo (inside a living organism) devices are artificial devices put into the human body or living organisms. Examples include *scaffolds, pins, plates, rods, screws, valves, sutures, grafts and fixations* which are manufactured to suit a variety of medical situations.
- Most in vivo devices are manufactured using conventional methods including Computer numerically controlled (CNC) milling, casting, forming, etc. Complexity of such goods are highly valued for in vivo applications. There are many examples of research being conducted with the aim of producing such goods by RM.

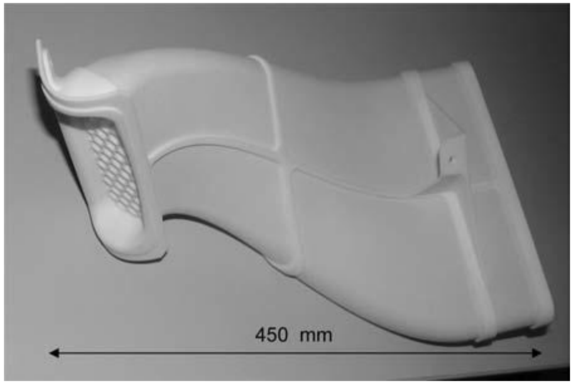


Automotive Applications

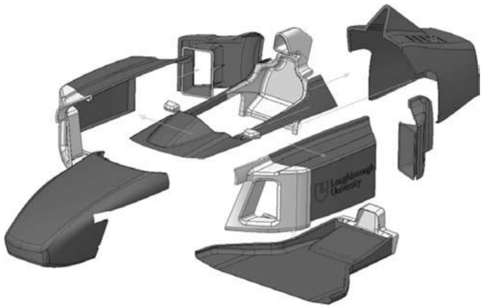
- Of all the potential areas of application for Rapid Manufacturing (RM), the automotive industry probably offers the most significant opportunities for changes in the way manufacturing is carried out.
- The design constraints currently imposed on the automotive designer owing to tooling design limitations will be removed. In both high and low-volume niche market models, the ability to individually customise areas of the car to suit customers' requirements would have a particular impact in areas such as *ergonomics, where parts could be manufactured to make the overall comfort fit of the car suit the customers' needs*.
- At the moment the ability to do this is very limited due to restrictions imposed by tooling. With the linking of technologies such as scanning and additive manufacturing, customisation becomes very real.
- A major benefit of the ability to manufacture parts directly by RM is the lack of manufacturing design constraints. This allowed assemblies of parts to be reduced into single components.

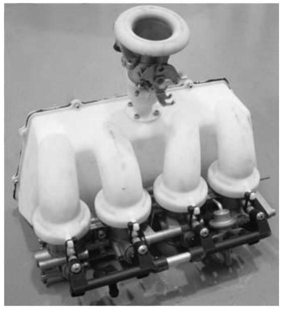
- The use of the Rapid Prototyping (RP) technologies has been commonplace in the development of Formula 1 (F1) racing cars.
- With the advent of materials with better functional properties it did not take long for this industry to realise that these parts could be fitted directly to the cars, thus allowing quicker modifications to be made at a greatly reduced cost.



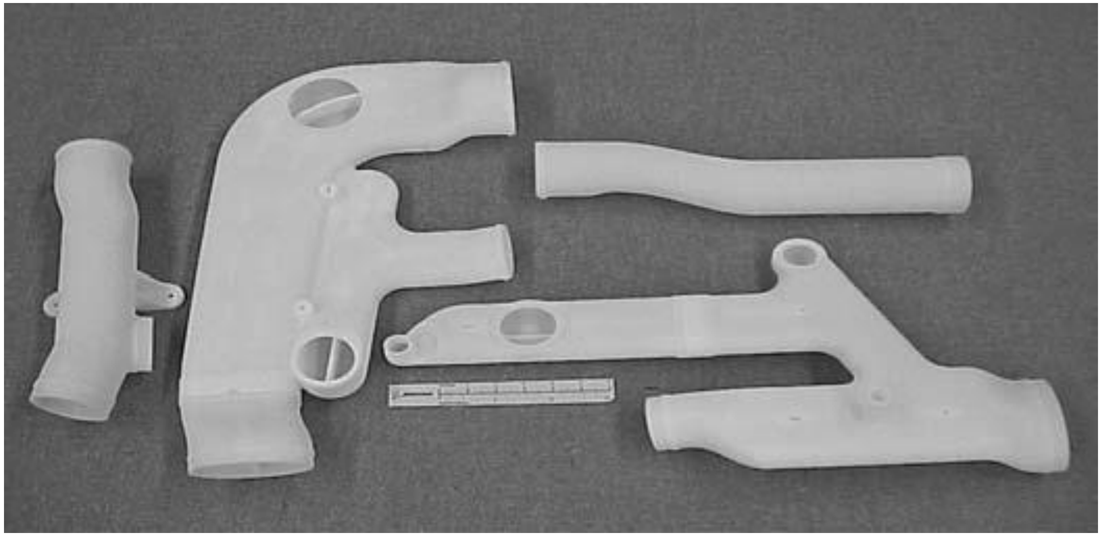


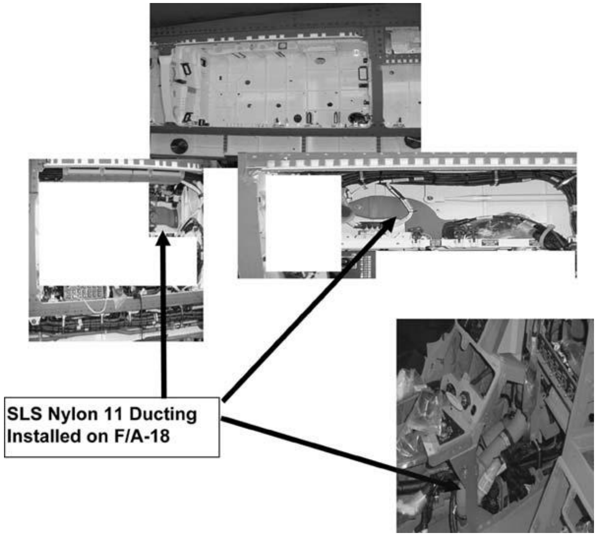
Formula Student Cars →





- The benefits of RM in aeronautical industry is design flexibility, no tooling and just-in-time delivery, all contributed to the end customer accepting and allowing this technology to be implemented.
- The US Navy partnered with the Boeing Company with the goal to add an additional cooling system on the F/A-18.
- Given the limited space in the jet fighter, cooling ducts needed to be designed such that the ducting could be accommodated in the space restriction while simultaneously meeting the goals.





- When planning a mission to the International Space Station (ISS), NASA's traditional approach has been similar to how one might prepare for a long camping trip: bring everything, 'cause we're not going home.
- When you're 200 miles from Earth, you want to make sure that you have all of your necessary supplies, from bolts to cable mounts. NASA's "better to be safe than sorry" approach, however, means that a vast majority of parts stored on ISS are never used.
- To lighten the load and reduce costs, NASA is using the ISS as a testbed to demonstrate a way of rapid manufacturing the necessary parts in space.

- It is possible to stabilise beautiful colours for RM lighting objects, which looked more like amber than plastic.
- Several ideas surfaced on how to make products with self supporting structures or collapsing and nesting products for selective laser sintering (SLS). Figure shows a series of nested lampshades made by SLS.
- When one talks about textiles, people always think of cotton, wool or other soft materials. However recently, rapid manufacturing methods have been used frequently in the production of textile products, especially for individual uses.