Project “PnP”: Pick-and-Place

THE CONTEXT:
A strategically important Gondwanan manufacturing industry is facing a challenge in material handling – unfortunately as a result of poor systems engineering and risk management. In a congested location, new infrastructure in the form of an overhead bridge structure to carry slurry has been introduced at great expense, but, the planning process failed to account for the spatial impact it now has on moving other product in specialised spherical containers between a recently recommissioned processing plant and the corresponding warehousing facilities. The slurry bridge significantly bisects and limits the space between the plant and warehouse facilities. In the new constrained environment, the old handling system will not work. Therefore, tenders are being called for a new and novel approach to moving the spheres.

Output from the processing plant is presented at three levels and is to be transferred to the warehouse which has similarly spaced receiving stations, also at three levels. While there is an ability to shuffle containers in the warehouse it is preferable that the new handling system minimise additional work in the warehouse.

The Gondwanans have aptly described the project as “Pick-and-Place”, have contracted this to “pick’n’place” and now refer to it as Project PnP. For them it has a high priority for resolution.

THE CHALLENGE:
The challenge is to design a prototype system to meet the needs of the Gondwanan industry. The industry is important to the Gondwanans and the product is highly valuable yet volatile. Therefore, for safety reasons, an effective and efficient unmanned automatic system is perceived by the Gondwanans to be most appropriate. This concept frames their call for tenders and the competition they are conducting.

Fortunately, teams of engineering students from Earth are about to visit Gondwana as part of their work experience programmes. On previous visits such engineering students have rendered invaluable assistance with solutions to similar engineering problems, and the Gondwanans again are hoping to benefit from the ideas of the innovative budding engineers.

Objective
The objective is to design, build and prove a prototype system in a laboratory environment that serves to transfer a payload of game balls on the defined track in accordance with the rules. In context, can you design the best system to pick and place product in the form of spherical containers between production and warehousing facilities?

Can you assist in Project PnP?

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Details follow:
• Competition Guidelines
• Competition Rules
• Frequently Asked Questions
• Further Competition Details
• Spirit of the Competition

Document Control
Version 1.0 07/02/2011
Version 1.1 18/02/2011 – G16 modified to reflect 90x19 bridge timber members (as available from Bunnings)
Competition Guidelines

(Version 1 Released: 07/02/2011)

ELIGIBILITY

G 1. Teams of notionally four first or second-year, nominally mechanical-engineering students, in Australian or New Zealand universities (or other universities by arrangement), may enter the competition. Teams of three or four are strongly recommended.

NOTE: It is recognised that some campuses are using the Warman as a 1st Year project and that team sizes may be necessarily forced for logistic reasons to be larger than 4. Both year and size variations are acceptable.

SAFETY

G 2. Safety is of paramount importance when participating in this competition. All engineers should know that injury and damage to equipment and the environment occurs when the control of energy in a system is lost.

G 3. As appropriate, protective clothing, footwear, safety glasses or full face masks should be worn by students working on systems during construction, during testing, and during competitions.

G 4. Students are encouraged to carry out a risk assessment for their system prior to campus testing. Students are encouraged to embrace risk management in their own activities and may need to demonstrate safe operation and produce risk assessment documentation in order to compete in either the campus heat or at the National Final.

G 5. Compressed gas systems may be used but students must gain local coordinator approval based on a safety assessment.

Such systems presented at the National Final will be examined against the following principles and must be acceptable to the National Coordinator:
- Home fabricated pressure system components are not to be used unless the pressure is considered to be low.
- Commercial components should be used (unions, vessels, cylinders, lines) unless the pressure is low.
- Up to 550 kPa (approx 80 psi) may be considered low pressure if such pressure is held inside a plastic drink bottle pressurised by a bike pump. Such a system must be well constrained to prevent projectiles exiting in the event of a failure. For example, an outer, non-pressurised shield shall be included over plastic bottle pressure vessels, to take any sting out of a rupture.
- Evidence of proof testing of compressed gas systems shall be provided.
COMPETITION TRACK, EQUIPMENT AND ENVIRONMENT

G 6. The competition track shall be fabricated using primarily two sheets of Medium Density Fibreboard (MDF), each with nominal dimensions 2400 x 1200 x 18 mm, arranged end to end as shown in Figure 1 and Figure 2. The supporting frame may be fabricated by any convenient method. The fabrication collectively is referred to as the competition “track”.

NOTE: The MDF sheets as supplied in the ACT are slightly larger than the nominal 2400 x 1200 dimensions. They are 2420 x 1210. They do not need to be cut down. The 12 x 12 DAR fences (see rule G17) on the board extremities are flush with the edge of the as supplied boards.

G 7. The two MDF sheets and relevant attached features are identified respectively as track segments 1 and 2.

G 8. The tops of the two primary MDF sheets shall collectively define the competition base plane which is nominally horizontal. The heights of the track segments shall be adjusted so that there is no step between the two track segments.

G 9. The competition base plane shall be no less than 300 mm above the supporting floor at the National Final.

G 10. Track segment 1 has the “pick-board” arranged at a 75 degree angle to the horizontal at one end and it joins with track segment 2 at its other end. It also incorporates an overhead “bridge” structure. (see Figures 1 and 2)

G 11. Track segment 2 has the “place-board” arranged at a 60 degree angle to the horizontal at one end and it joins with track segment 1 at its other end. It also incorporates the start zone. (see Figures 1 and 2)

FIGURE 1 – TWO VIEWS OF THE PROJECT “PnP” COMPETITION TRACK
pick-board to the right end of the track as depicted, inclined place-board to the left
FIGURE 2 - PROJECT “PnP” COMPETITION TRACK PROFILE
G 12. The pick-board, with square cut edges (not bevelled) has 9 pairs of 9.5mm dia multi-grooved timber dowel pins projecting 50mm perpendicularly from its face. The pin pairs are arranged as shown in Figure 3 where the centre to centre separation of pins in a pair is 40mm.

Note: A 2.4m length of multi-grooved dowel can be obtained for under $5 (priced at Bunnings) and it is recommended that the pick-board be through drilled to set the 50mm projection. Broken or damaged pins should be relatively easy to replace if necessary.

G 13. The line of contact of the pick-board formed by its bottom corner edge with the competition base plane defines a reference from which other track features are measured. The pick-board is to be appropriately bracketed and supported to provide a rigid inclined plane at one end of track segment 1. The supporting structure must not restrict the clear space to the sides of the track.

G 14. The place-board with square cut edges (not bevelled) presents 9 “warehouse” compartments as detailed in Figure 4, each capable of receiving balls. The compartments are fabricated using 70x19mm timber dividers glued and screwed to the 60 degree inclined plane. The place-board is to be appropriately bracketed and supported to provide a rigid inclined plane at one end of track segment 2 and positioned such that its line of contact formed by its bottom edge with the competition base plane is 4350mm from the line of contact of the pick-board. The supporting structure must not restrict the clear space to the sides of the track.
G 15. A start zone will be defined on track segment 2 by two transverse lines (scribed and highlighted with a fine tip permanent marker) at distances of 3200mm and 3800mm from the line of contact of the pick-board.

G 16. A bridge structure using 400 90x19mm timber members will span the track with its centre at a distance of 2000mm from the line of contact of the pick-board. A clear opening 410 mm high across the width of the track will be defined by the bridge. The inside faces of the vertical supports will be flush with the edges of the track. Other elements as necessary can be used to support the bridge below the competition base plane such that it is a rigid structure.

G 17. Between the pick and place boards, the longitudinal edges of the track segments shall be fenced with 12 x 12 DAR (Dressed All Round) timber strips mounted on the top (track base plane) with their outside edges flush with the sheet edges. The strips will be mounted by countersunk screws (100 mm spacing) on the top surface of the sheets. The strips are considered to be within the start zones.

**NOTE:** The 12 x 12 DAR fences should be considered as guides rather than barriers built to resist high collision loads. Damaging the fences is considered to be damaging the competition site and will cause a zero run score to be recorded.

G 18. All exposed surfaces of the MDF and timber will be brush coated with one coat of Wattyl Water Based Estapol Clear – Satin followed by two coats of Wattyl Estapol Matt.

G 19. The payload used for the competition will be (6.5cm) Bestway ® Splash and Play air filled “Game Balls” (see Figure 5).
FIGURE 5 - 2.5" (6.5cm) BESTWAY® AIR FILLED GAME BALLS

NOTE: The balls can be purchased from ToyWorld which has outlets Nationwide.

G 20. Nine game balls will be differentiable by colour in three groups (i.e., 1-3 Green, 4-6 Yellow and 7-9 Red).

G 21. Teams must accept that the presence of bright lighting and photography including flash and infrared systems are part of the competition environment.

PROTOTYPE SYSTEM

G 22. Participating teams shall present a prototype system that serves to transfer a payload on the defined track in accordance with the rules.

G 23. The payload game balls, initially located by resting them on dowel pin pairs on the pick-board in a predefined arrangement are intended to be transferred by the prototype system to the compartments on the place-board.

G 24. Systems that are deemed by the officials and judges to be hazardous will not be permitted to run. Employing any form of combustion is considered hazardous.

G 25. Campus organisers are free to modify the rules and or competition track for their local competition but the guidelines and rules as stated shall be strictly adhered to at the National Final.

RULE WORDING

G 26. The language of the rules is tiered. Those clauses expressed as “SHALL” are mandatory and failure to comply will attract penalties which in the extreme could lead to disqualification. Those expressed as “SHOULD” or “MAY” reflect some level of discretion and choice.
Competition Rules

MATERIALS AND MANUFACTURE

R 1. Students SHALL manufacture and fabricate their prototype system themselves using commonly available materials, components and methods.

NOTE: At the National Final Campus Organisers may be required to confirm that the systems presented have been appropriately manufactured in keeping with the spirit of the competition.

PROCEDURE

R 2. The mass of the team’s system will be measured by an official. The system gross mass SHALL NOT be greater than 8 kilograms.

R 3. The team will be called to the track side and, when ready, an official will signal that the setup time has commenced. The team SHALL be allowed a maximum of 120 seconds for setup. In this time they are to set up their system in the start zone. No modifications can be made to the game balls in this process.

R 4. While the team is setting up, officials will position the payload in the form of the nine game balls on the pick-board, with consistent colours on each row (i.e., three red balls on the top row, three yellow balls on the middle row, and three green balls on the bottom row).

R 5. Contact SHALL NOT be made by team members or their system with the competition track before setup commences.

R 6. Contact SHALL NOT be made during setup of the system with any portion of the track other than the start zone. The team will indicate to the appropriate official when their setup is complete.

R 7. During setup and in the region of the start zone only, the team MAY use, for the purposes of setup, additional objects not considered part of the “system”.

R 8. After setup and prior to running, everything placed and left on the competition track with the exception of the balls SHALL be considered to be part of the system.

R 9. After setup and prior to running, the system will be subject to a volume constraint. For a valid run, the system SHALL be wholly contained within a 400 mm cubic envelope having one face in the competition base plane. The volume condition will be physically checked by an official.

R 10. After setup and prior to running, the system SHALL be both stationary and, in a view perpendicular to the competition base plane, not project beyond the edges of the start zone. The positioning condition will be physically checked by an official.
R 11. After set up and prior to running, the system SHALL NOT be held or supported
or contacted by anything other than the competition base plane and it must be ready to
start. This prohibits team members from restraining by personal contact a ready-to-
release system. Systems should be capable of remaining in the set up condition
indefinitely.

R 12. On instruction and by a signal from the “official starter”, the run will commence.
A valid run SHALL finish within 120 seconds. This will be judged by an official.

R 13. The system SHALL be started using a single action that does not impart motion or
ergy to the system. A single-action start may employ a simple instrument not
considered part of the system, e.g. using scissors to cut a string.

R 14. After performing the single-action start, team members SHALL NOT control or
touch the system in any way during the run. Wireless control is specifically prohibited.
If team members choose to intervene to protect a system that is malfunctioning, a zero
score for the run shall be recorded.

R 15. During the run the system SHALL NOT come into contact with anything below
the competition base plane. The exposed surfaces of the 12 x 12 DAR fences above the
competition base plane can be contacted.

R 16. During the run the system SHALL NOT work over the top of or around the sides
of the bridge structure.

R 17. At the completion of the run, the overall system SHALL cease both translation on
the competition track and gross motion above the competition base plane and remain in
this state indefinitely relative to the competition track. Mechanisms and items in the
system may continue to move but no further functions can be executed.

R 18. The team will indicate to the timekeepers when they declare their run to be
complete. However, the time keepers SHALL make the final judgment as to when the
system ceases translation, rotation and all functions have ceased. The recorded time may
exceed the team’s declaration.

R 19. To ensure that judging has been completed teams SHALL NOT retrieve their
system or assist in gathering other items until directed by an official.

R 20. Systems SHALL NOT damage or contaminate the competition track. Teams
presenting systems that damage the track may be disqualified from the competition.

EXPLANATORY NOTE: A component of the system left simply on the competition
track does not constitute contamination. An example of contamination would be a sticky
residue requiring significant effort to remove it, with the possibility of permanent change
occurring to the surface finish.

R 21. As directed, teams MAY attempt two runs.

R 22. The system MAY be modified between runs but the mass, volume and time
constraints must be satisfied for a run to achieve a non-zero run score.
R 23. Violations of procedural rules SHALL result in a zero run score being recorded.

R 24. The judges’ decisions on all matters pertaining to the competition SHALL be final.

SCORING

R 25. Better systems will achieve the objectives of transporting the payload with higher effectiveness whilst adhering to the timing, volume and positioning constraints. The run score SHALL be calculated using the following formula and is based on the end state of the nine game balls.

\[ \text{RUN\,SCORE} = \text{NPicked} - \text{NLost} + \text{NPlaced} + \sum_{i=1}^{9} \text{CompBallVal}(i) \cdot \text{CompVal}(i) \]

Where:
- \( \text{NPicked} \) = Number of balls picked
- \( \text{NLost} \) = Number of balls lost
- \( \text{NPlaced} \) = Number of balls placed
- \( \text{CompBallVal}(i) \) = Maximum value of placed balls in compartment \( (i) \); for \( i=1,9 \)
  - 0 if no balls placed in Compartment \( (i) \)
  - 1 if only Green ball(s) in Compartment \( (i) \)
  - 2 if Yellow and no Red ball(s) in Compartment \( (i) \)
  - 3 if a Red ball(s) in Compartment \( (i) \)
- \( \text{CompVal}(i) \) = Value of Compartment \( (i) \); for \( i=1,9 \)
  - 2 if bottom row \( (i=1,3) \)
  - 2 if from middle row \( (i=4,6) \)
  - 3 if from top row \( (i=7,9) \)
- \( \text{SYSMASS} \) = Integer (mass of system in grams)
- \( \text{RUNTIME} \) = Integer (Runtime in seconds)

The maximum score achievable from a valid run is 63. This is achieved with one ball placed in each compartment with the row on which a ball is placed corresponding to the row from which it was picked. Where multiple balls are placed in a compartment, only the higher valued ball contributes to the compartment score \( \text{Value(\text{Red})} > \text{Value(\text{Yellow})} > \text{Value(\text{Green})} \).

R 26. At the end of a run, a ball simultaneously in contact with the pick-board and the system SHALL be classified “picked”.

R 27. At the end of a run, a ball simultaneously in contact with the place-board and the system SHALL be classified “placed”.
R 28. If a ball is on the pick-board, on the place-board or fully supported by the system at the end of the run, it SHALL NOT be classified “lost”. For all other conditions, a ball SHALL be classified “lost”. The event of a ball or balls being lost does not result in a zero run score (unless all that are picked are lost).

R 29. The score for each compartment SHALL be defined by the highest valued ball held in that compartment.

R 30. The Warman Competition Score SHALL be the higher score achieved from either run plus half of the score achieved from the other run and the highest Warman Competition Score will be declared the winner.

R 31. If equal Warman Competition Scores are recorded by teams, teams tied SHALL be ranked based on the RUNTIME of their highest scoring run.

R 32. If the RUNTIMEs of the top ranked teams are within 10 seconds of the fastest, the teams so bracketed SHALL participate in a sudden death run-off to determine the overall places.

R 33. In the event of a run-off, each team will make one run. If an equal score is again recorded, each team will make another run. If after a third such run, the score is still equal; the team with the shortest run time in the third run-off run SHALL be declared the winner.
Frequently Asked Questions

(Version 1 Released: 07/02/2011)

1. Does the system have to stay in contact with the competition track at all times?
No but the rules do define what can be legally contacted.

2. Can part of a system be “discarded” off the track without penalty?
No, this would violate the rules and lead to a zero run score.

3. At the end of a run, could a system be supported on the competition track and have a part over the “outside” edges of the track in plan form projection and not receive a penalty?
Yes, you could have a part in space with no competition track component under it as long as nothing other than legal surfaces of the track are contacted by the system.

4. When is a system deemed to be stationary at the completion of the run?
The stop instant will be interpreted as the later of when all the contact points between the system and the competition site come to rest and when the functions being performed are observed to have ceased. It must be clear that the system could remain in the end state indefinitely. Some wobbling in the structure is acceptable but gross rotations are not.

5. Autonomous – does this mean that the system on the track can not receive input or instructions from a device off the track (such as a computer)? Or does it mean that the system on the track can receive input from a device off the track (such as a computer) but that device (computer) can not be manipulated by a team member during the run? An example of the second would be if the system was controlled by motors that ran to a pre-programmed route transmitted from the computer.
Autonomous in this competition implies every control system for the system is to be part of the system on the track and fit within the start volume. No remote-to-the-track control systems of any sort can be used (manual or pre-programmed, hard wired or wireless). Such configurations would be considered to be part of the system and violate position and volume constraints.

6. Are programmable chips allowed?
Yes, you can use a programmable chip, but there is to be no remote communication during the run.

7. What is the allowable voltage and power of any employed electrical systems?
There are no restrictions this year but it clearly needs to be safe.
8. **The system mass, SYSMASS, does not influence the scoring. Why is it included?**

It is included to validate the maximum mass defined. Failure to comply with the stated maximum mass will result in disqualification. A large mass fundamentally indicates inefficient design. Further, designs needing to be transported to the National Final need to be light and small enough to be accommodated by air travel.

9. **Can LEGO and other off-the-shelf items be used?**

Commonly available components such as LEGO and toy and machine parts are able to be used. The spirit of the competition is that students manufacture and fabricate their system themselves, meaning that professionals are not engaged to do it for them. It is possible for some assistance to be obtained (e.g., for a weld) but this should be minimal or where possible be done by the students themselves. The production of major components should not be outsourced.
Further Competition Details

(Version 1 Released: 07/02/2011)

NATIONAL FINAL

It is planned that the Weir-Warman National Final will be held Friday 23 - Sunday 25 September 2011 in Sydney at the Powerhouse Museum (PHM).

Prizes for Campus Winners and National Podium Places will be awarded at the National Final. A National Final “Judges’ Prize” may also be awarded.

The planned format will have students gathering at the PHM on Friday morning. Students should be able to gain access to the PHM and their “pit” area from 9 AM and are asked to be present at the PHM by 10 AM. A tour of Weir Minerals Ltd will follow. The PHM closes at 5 PM each day. Scrutineering and additional judging will be conducted on Saturday and there will be briefings, presentations and practice sessions held on Saturday. The actual running of the Final and the National Final Dinner will be on Sunday.

A team registration form is available on the competition web site – please submit to Engineers Australia (EA) as early as possible. Travel arrangements are coordinated by EA. Team details are required by no later than 8 August (unless otherwise advised).

Teams registering and accepting the invitation and sponsorship to participate at the Final also accept that their names and photographs and video of them can be used for publicity purposes by both EA and Weir Minerals. All team members and attending campus organisers will be required to sign an appropriate authority in relation to this use.

In meeting costs, the competition sponsorship funds two students per team. Depending on EA funding, it is hoped that Campus organisers will also be funded. Campuses will be billed for additional students and for people who do not travel but for whom arrangements are made.


**Spirit of the Competition**

Although the rules may look rigid you will find that they have been written in a way which allows, and in fact encourages, creative solutions. This is not always the case in real-world engineering projects. In this project and competition, the rules are there because we have tried to be very clear on points which will be important when student groups come together for the National Final. For this reason, it is essential to work with your campus organiser from an early stage, and for the campus organiser to verify decisions with the National Organiser so that everyone has the same understanding of the meaning of the rules.

If you think you see a loophole, clear it with your campus organiser before you rely on it in competition. Even if it is accepted at the local level, you might be in for a shock at the national level where the interpretation might be different. Provision will be made for confidentiality, so your idea will not be passed on to other students.

It is highly recommended that all students communicate with their campus organiser and that if a ruling is required by the National Organiser; this is sought by the campus organiser. Students SHOULD NOT contact the National Organiser directly for an individual ruling.

The competition track will be made with reasonable care but because it is a real engineering object it may well be “wrong” in various small ways. For example the surface might have a slight longitudinal slope. Your team is expected to consider these possibilities in your design, and develop a system that can function even if the competition track has slight imperfections. In other words, you are not allowed to blame failure of your system on some minor imperfection with the competition track.

**A FINAL COMMENT ON SAFETY**

*Please be aware that in 2003 during a campus competition, a student was lucky to escape serious eye injury when a device went off unexpectedly. While Campus organisers run their own competitions independently, they are strongly encouraged to consider all aspects of safety in relation to the conduct of their competition.*