Delta Design   THE DESIGN TASK

Project Manager's Primer appended.

1.1   Introduction

Congratulations! You are now a member of an expert design team. Your collective task will be to design a new residence suitable for inhabitants of the imaginary Deltoid plane. These written materials, provided to help you prepare for this task, are organized in four sections.

The next section provides an overview of life on the Deltoid plane, DeltaP as it is known to the natives. The following section describes your team, and the final, your design task. A second handout, different for each team member, provides the specific information you will need to perform the role you have been assigned within your team. Each team member will contribute different expertise to the project, and each has different design responsibilities to fulfill. All must work together for your team to create a first-rate design.

1.2   Life on DeltaP

Life on DeltaP, residential and otherwise, is quite different from what you have grown accustomed to here on Earth. First off, DeltaP is a plane, not a planet, so your team will be designing in two-dimensional rather than three-dimensional space. If your design "meets spec" and is considered attractive and functional by your Deltan clients, one view on a single sheet of paper will convey to those responsible for constructing it all the information they need to do so.

Work in Progress
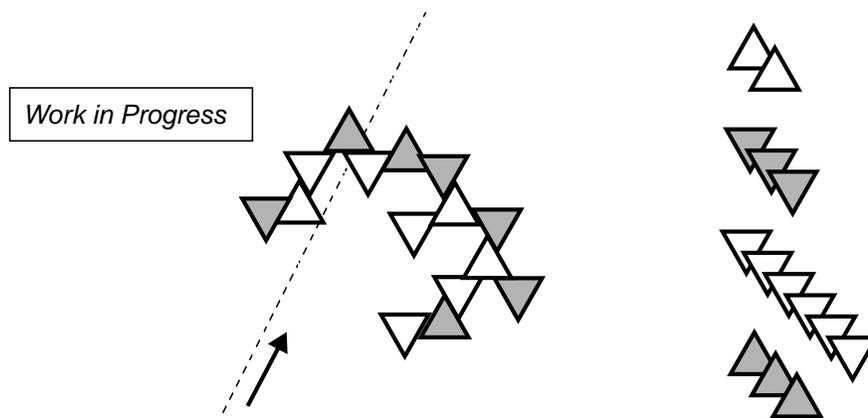
The view on this single sheet may not be quite what you expect, however, because in addition to lacking a z axis, Deltoid space has unfamiliar relations between the x and y axes as well. What we think of as "perpendicular" is hopelessly skewed to a Deltan, and vice-versa. In our units, a right angle on DeltaP measures 60° or $\pi/3$ radians. Thus all sides of an equilateral triangle form lines considered perpendicular to all others. If there were such a thing as a "circle" on DeltaP, it would be composed of only $4\pi/3$ radians.

But there is no such thing as a "circle" on DeltaP, nor even the concept of continuity embodied therein. In this flat though angular world, residents construct their artifacts strictly with discrete triangular forms. Of these, the equilateral triangle -- with its three perpendicular sides (!)-- is considered the most pleasing. Accordingly, your team will design the residence by assembling into a
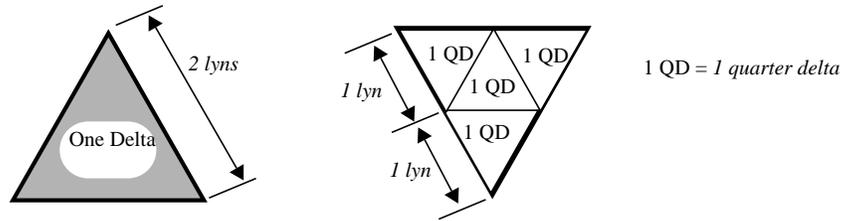
cluster the most prized building materials on DeltaP, equilateral triangular components called "deltas." Deltas come in red and blue versions and always measure *2 lyns* per side. Four "quarter-deltas", *QD*s, triangular units of area measure with sides of *1 lyn*, fit within a delta.

Lyns? QDs? Not surprisingly, Deltan systems of measurement are as unfamiliar as that for spatial coordinates. Table 1 summarizes the measurement schemes on DeltaP that you will need to know to carry out your design task.

All of DeltaP's units of measure share the divisibility and extensibility conventions of the metric

TABLE 1.   **Measurements on DeltaP**

Measurement	Unit of Measurement	Symbol
Time	Wex	wx
Distance	Lyn	ln
Area	Quarter-Delta	qd
Heat	Deltan Thermal Unit	DTU
Temperature	Degrees Nin	°Nn
Force	Din	Dn
Moment	Lyn-Din	LD
Currency	Zwig	!

system; in the measure of time, for example, there are both microwex (μwx) and megawex (*Mwx*). In relation to the attention-and life-spans of Deltans, these units are roughly equivalent to seconds and years, respectively, here on Earth.

As building components, deltas have functional and aesthetic characteristics that are more complex than their simple form and even dimensions would suggest. Especially when assembled into a cluster, as you will be doing, they behave in interesting ways. Deltas conduct heat among themselves, radiate heat to outer space, melt if too hot, and grow if too cool. Red deltas produce heat. All deltas are subject to DeltaP's two-dimensional gravity (which is itself subject to axial shifts during DeltaP's not-infrequent gravity waves). Three different kinds of cement are needed to join them together, and joint alignment with respect to gravity affects ease of production as well as

structural integrity. Different colors and different quantities of deltas cost different amounts of money per delta, and can be assembled in clusters that are either exceedingly ugly or very attractive to the Deltans. Your task will be to create a design that meets prescribed goals for all of these characteristics.

1.3   Design Team Roles & Responsibilities

Your design team is organized such that each of you will be responsible for a subset of the design goals. One of you will be PROJECT MANAGER. Your main concerns will be with cost and schedule, the interpretation and reconciliation of performance specifications, and negotiations with the contractor and client. You want to keep costs and time-to-build at a minimum, but not at the expense of quality. When your team submits its final design, the project manager must report the estimated cost (in zwigs) and the time (in wex) that it will take to build.

Another of you will be the STRUCTURAL ENGINEER. Your main concern will be to see that the design "holds together" as a physical structure under prescribed loading conditions. You must see to it that the two points at which your structure is tied to ground are appropriately chosen and that continuity of the structure is maintained. When your team submits its final design, the structural engineer must attest to its integrity by identifying the strongest and weakest joints, and estimating the average load on all joints expressed as a percentage of the failure load.

Another of you will be the THERMAL ENGINEER. You will want to insure that the design meets the "comfort-zone" conditions specified in terms of an average temperature. You must also ensure that the temperature of all individual deltas stays within certain bounds. When your team submits its final design, the thermal engineer must estimate internal temperature and identify the hottest and coldest deltas.

Finally, one of you will be the ARCHITECT. Your concern is with both the form of the design in and of itself and how it stands in its setting. You must see to it that the interior of the residence takes an appropriate form and that egress is convenient. You should also develop a design with character. When your team submits its final design, the architect should be prepared to present a sketch and discuss generally how and why the Deltans will find the residence attractive and functional. The architect will also be asked to estimate a few more quantitative measures of architectural performance.

The following section describes the specifications that your design must meet to be accepted by your clients on DeltaP. Familiarize yourself with these specifications. Then, for schooling in your specialty, turn to the separate primer you have received that discusses the science and technology of your domain. The primer contains the knowledge and heuristics you will need to estimate the design parameters for which you are responsible. If you have questions that it does not answer, do not hesitate to ask. You should be expert in your role before your team begins the design phase.

1.4   The Design Task

Your Deltan clients have cleared the space shown on the site map and come to your team with their need for the design of a new residential cluster. The cluster itself must meet the following specifications.

The client wants the cluster to provide a minimum interior area of 100 QDs (Each diamond on your girded site map defines an area of two QDs). The shape of this space, which can of course exceed the minimum, is a matter of design. The client has expressed enthusiasm for the newer

mode of segmenting interior space, a mode that breaks with the two-equal-zone tradition and values the suggested privacy of nooks and crannies. Still the space must be connected, i.e. no interior walls can cut the space into completely separate spaces. There must be one and only one entrance/exit.

The client is known to be color sensitive blue; too much blue brings on the blues, so to speak. No more than 60% blue ought to be allowed; certainly blue deltas are not to exceed 70% of the cluster.

The residence, as all clusters, must be anchored at two points and two points only. There is a limit to the amount of force each anchor can support, as well as to the amount of internal moment each joint can withstand. Exceeding either limit would cause catastrophic failure and send the unwary residents tumbling into the void. The cluster should be designed for a life of thirty megawex. Gravity waves, rare but always possible, should be considered.

The average interior temperature must be kept within the Deltan comfort zone, which lies between 55 and 65 ^{o}Nin. The temperature of the elements themselves must be kept above the growth point of 20 ^{o}Nn and below the melt-down point of 85 ^{o}Nn. Delta temperatures outside of this range will result in catastrophic structural failure with little more warning than excessive load.

All of this -- design, fabrication and construction -- must be done under a fixed budget and within a given time period. At your team meeting you are to develop a conceptual design that meets or exceeds all design goals. When each team submits their design, individual members will be asked to report design performance on parameters for which they are responsible.

TABLE 2. **Summary of Design Specifications**

Functional Internal Area	100 qd
Maximum Cool Deltas (% Total)	60-70%
Average Internal Temperature Range	55-65 ^{o}Nn
Individual Delta Temperature Range	20-85 ^{o}Nn
Maximum Load at Anchor Points	20 Dn
Maximum Internal Moment	40 LD
Overhead Factor -K	(varies)
Total Budget	! 1400.00

Delta Design   PROJECT MANAGER PRIMER

1.1 Introduction

As project manager, your main concerns are cost and schedule, the interpretation and reconciliation of performance specifications, and negotiations with contractor and client. You want to keep costs and time-to-build at a minimum, but not at the expense of quality. When your team submits its final design, you must report the cost and time that you estimate will be required to build it. These estimates will be in zwigs (!) and wex, respectively.

As an experienced project manager, you know that all specifications are prone to slip during the conceptual design phase, and that budget and schedule, your specific responsibilities, are the most vulnerable. You have already realized that both are likely to be binding constraints, and further, that the Deltans are tight with a zwig and anxious to move in. Like clients everywhere, they desire a better residence then they can comfortably afford.

1.2 Estimating Project Costs

Your job of estimating project cost has been greatly simplified by finding a supplier-contractor that quotes material costs inclusive of delivery and most assembly charges. The cost schedules presented below for buying deltas and the cement needed to glue them together thus reflect near-final costs, with two important exceptions. One source of additional cost comes from the modular construction techniques used on DeltaP: material prices cover the labor cost to assemble deltas into modules, which is done at the factory, but not the on-site cost of positioning and joining these modules into the final structure. The second additional cost is overhead, which covers, among many other things, the cost of paying your design team.

To estimate the cost of your team's design:

- figure the cost of the deltas used;

- figure the cost of the cement needed to joint them;

- figure the number of modules and the cost to join them; sum all these up and multiply by the overhead rate.

To estimate how long it will take to construct your design:

• identify the separate modules;

• determine how long it will take to construct each one;

• determine how long it will take to assemble them at the site;

• sum these up.

1.3   Delta Costs

The cost of deltas varies by color and quantity purchased. The price break for blue deltas is at 16 units: blues cost !10 apiece if fewer than 16 are purchased, !6 for 16 or more. The price break for red deltas is at 20 units: reds cost !8 each if fewer than 20 are purchased, !6 for 20 or more. These costs are shown in Schedule 1.
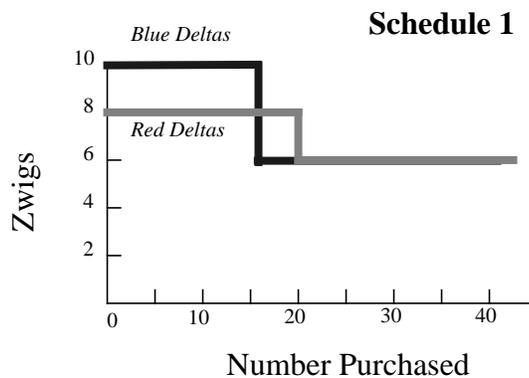
Schedule 1

Schedule 2 illustrates how the total cost of deltas purchased varies with color composition. The y axis shows total ! cost and the x axis show the number of red deltas used. The three graphs show the color-mix variance in total delta costs for structures using a total of 30, 40, and 50 deltas, respectively. This schedule can help you calculate the most economical color mix for a given structure size.

Schedule 2
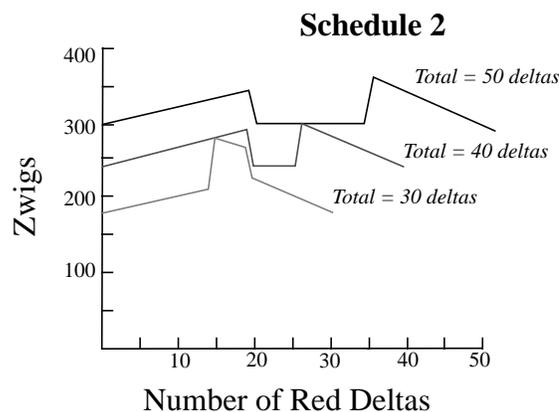
1.3.1 Cement Costs

You will need to purchase three different types of cement, at three different costs, to assemble deltas into your structure. Three types --R^2, B^2, and RB -- are required because different types of joints require different types of cement. R^2 (pronounced "r squared") is the red-red binder needed

to bond one red delta to another red delta. *RB,* the most expensive, is the red-blue binder that bonds a red delta to a blue delta. Finally, B^2 is the least expensive and bonds two blue deltas. The following costs apply;


TABLE 1.   **Cement Costs**

Cement Unit Costs	
R^2	!10 / lyn
RB	!20 / lyn
B^2	!5 / lyn

Note that the cost of fastening one delta to another will be determined by the length of contact between elements as well as by their respective colors: the longer the joint, the more glue is required. A fully overlapped 2 lyn joint between a red and a blue delta will cost !40; hardly pocket change.

2 lyns

One Delta
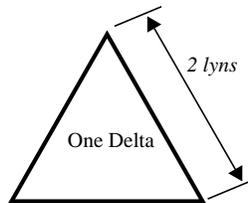
1.3.2 Module Joining Costs

Should your team's design be selected, construction will proceed in two stages. In the first stage, individual deltas are joined into modules. This takes place at the factory, where the supplier firm has developed jigs and fixtures that simplify the task, allowing them to accurately predict and therefore include the costs in the quoted prices for deltas.

Work in Progress

indicates module boundary

module 1

module 2

module 3

module 4

g
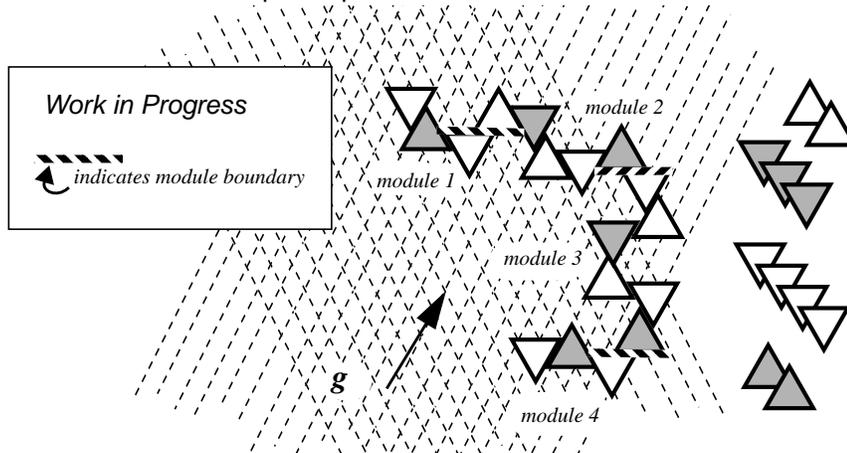
The individual modules into which a given structure will be decomposed and constructed at the factory are easy to identify, because the boundaries between them are defined by the orientation of the joints relative to gravity. To an earthly eye, any intersection of two deltas that runs left to right, across the page, is a module boundary. The figure shows how this works. The design has 3 such joints, and therefore 4 modules.

When all modules are complete, they are transported to the site, joined together, and anchored to the plane. This on-site work is more difficult to cost out in advance, so the client will essentially have to pay whatever costs are incurred. Your experienced contractor, however, has told you that her rule of thumb for predicting them is to figure the cost of glue needed for the mod-

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ule-to-module joints and double it. Thus the approximate on-site cost to joint Modules 1 and 2 in the figure could be estimated as 1 lyn of length times !5 per lyn of BB cement times 2, or !10. These module-joining costs are *in addition to* the cost of cement used in joining Module 1 to Module 2.

1.3.3 Total Cost

The total cost to execute your design may be estimated by summing up the cost of deltas, cement, and module joinery, and multiplying the result by an overhead factor K:

Total Cost = K x (delta cost + cement cost + module cost)

Because K takes into account the cost of living on DeltaP and must be updated frequently, it is not included in this primer. Refer to the earlier handout entitled "The Design Task" for its value, or ask the instructor.

1.4   Estimating Time-to-Build

Estimating time-to-build is inexact, at best, but again your contractor has supplied some rules of thumb. Rough results are shown in the graph, but you will do better to figure them more precisely.

For each module consisting of three deltas or fewer, allow 2 wex;

For each module consisting of more than three deltas, allow 3 wex;

For each module-to-module joint, allow 4 wex;

Sum all of these up and double the result.

Time to Build

by average deltas per module.

Total Number of Deltas