考試科目	經濟學	所別	科管所 甲組	考試時間	4 月 18 日 (上) 午第 / 節 星期日 下

請注意：共 14 題選擇，1 題問答.

選擇題（一題 6 分）

1. All of the following household expenditures are included in consumption expenditure <u>EXCEPT</u>

   (A) purchase of corporate stock (B) purchase of hair styling

   (C) payment to a dentist for filling a tooth (D) purchase of a new purse

2. Which of the following will cause the demand curve for real money to shift to the left?

   (A) An increase in real GDP.

   (B) The expanded use of credit cards.

   (C) An increase in the price level.

   (D) An increase in the quantity of money supplied.

3. Firms A and B can conduct research and development (R&D) or not conduct it. R&D is costly but can increase the quality of the product and thus possibly increase sales. The payoff matrix is the economic profits of the two firms and is given below, where the numbers are millions of dollars. A's best strategy is to

   (A) conduct R&D regardless of what B does

   (B) conduct R&D only if B does not conduction R&D

   (C) conduct R&D only if B conduction R&D

   (D) not conduct R&D regardless of what B does

		Firm A	
		R&D	No R&D
Firm B	R&D	A: $25 B: $15	A: -$3 B: $60
	No R&D	A: $60 B: -$3	A: $50 B: $35

4.台灣目前貨幣政策中間目標爲

(A) 重貼現率

(B) 央行可轉讓定存單

(C) M2

(D) 同拆利率

(E) 以上皆非

備考	試題隨卷繳交

5.下列何者對台灣匯率制度描述正確？

(A) 是間接報價

(B) 是 currency board 制度

(C) 遠期匯市同時有無本金遠匯及有本金遠匯

(D) 台灣利率比美國利率高，故台灣利率下跌，有助於匯率升值

(E) 以上皆非

6.實質景氣循環理論 (real-business-cycle theory)利基於古典理論的基本假設，此理論主張：

(A) 勞動供給的變動是引起景氣循環的一個原因。

(B) 實質總供給為利率的函數

(C) 生產技術進步會引起產量的增加，造成好的景氣。

(D) 以上皆是

(E) 以上皆非

7. 風險中立者之效用曲線（U）具有何種特性？

(A) 效用曲線為 concave

(B) 邊際效用遞減不變

(C) $U[(a+b)/2]<(U(a)+U(b))/2$

(D) 不參加公平賭局

(E) 以上皆非

8.從量稅會對獨占廠商產生何種影響？

(A) 減少產量

(B) 抬高價格

(C) 利潤減少

(D) 以上皆是

(E) 以上皆非

9.已知某一商品之需求曲線與供給曲線如下，

$$D(p) = 6 - P \quad ; \quad S(p) = 3 + 2P$$

今對該商品每一單位課徵0.5元的稅收，則課稅前之均衡數量為多少？課稅後之均衡價格為多少？

(A) 5；2.25

(B) 3；3.75

(C) 1；2.25

(D) 1；3.75

(E) 以上皆非

10.在開放總體之下，採行固定匯率制度，則擴張性貨幣政策在下列那一種情況下最有效(使產出增加最多)

(A) 資本完全移動

(B) 資本不完全移動

(C) 資本完全移動和資本不完全移動都一樣無效

(D) 資本完全移動和資本不完全移動都一樣有效

(E) 以上皆非

11.假定簡單的凱因斯模型的消費、投資、政府支出、及租稅函數分別爲：

$$C = 80 + 0.8Y_D$$
$$I = 150$$
$$G = 100$$
$$T = 100$$

試求算均衡的所得?

(A) 1150；

(B) 1200；

(C) 1250；

(D) 1300

(E) 以上皆非

12.以下敘述何者爲是？

(A) Phillip Curve 告訴我們：失業率與物價上漲率成正向關係。

(B) 貨幣政策效果受存款準備率影響。

(C) Lucas 認爲政府可以藉由貨幣政策刺激景氣。

(D) 當投資陷阱產生時，財政政策無效。

(E) 以上皆非

13.以下對 Stackelberg 模型的敘述何者錯誤？

(A) 是一種逐步賽局（sequential game）

(B) 由產量的決定來進行賽局

(C) 由價格的決定來進行賽局

(D) 有 leader 與 follower

(E) 以上皆非

14.貨幣政策的信用傳遞過程的 credit cruch 指的是

(A) credit 的 demand 減少

(B) credit 的 supply 減少

(C) 同時減少

(D) 同時增加

(E) 以上皆非

問答（16 分）

1. 說明流動性效果、流動性陷阱與投資性陷阱的異同

考試科目	微積分	所別	科管所甲	考試時間	4月18日上 下午第3節 星期

以下每題 10 分，請遵守考試規則並保握時間。

1 $\int_{2}^{\infty} \frac{1}{x[\ln x]^2} dx = ?$

2 一公司的生產函數爲 $Q = f(L, K) = 24L^{\frac{2}{3}}K^{\frac{1}{3}}$，當勞力 L 從 27 單位增加爲 29 單位，而資本 K 由 8 單位減爲 7 單位時，請用全微分估計對產量 Q 的影響。

3 某廠商生產，B 兩種商品，其售價分別是 16 元及 20 元。如果 A，B 分別生產 x, y 單位時，其聯合成本函數爲 $C(x, y) = 0.01(x^2 + xy + y^2) - 800$。試問，使利潤最大的生產量（x, y）是多少？此時利潤是多少？

4 若 xy=4 ,請問 $f(x, y) = x^2 + y^2$ 有極小値時的(x, y)是多少？

5 試求 $\int_0^1 \int_0^{\sqrt{y}} \frac{xy}{y^3 + 2} dx dy = ?$

6 試求 $\int_1^2 [(x-1)^5 + 3(x-1)^2 + 5] dx = ?$

7 若 $y = 2 - 3x^2, u = x^3 + 1$，當 $u = 9$ 時，試求 $\frac{dy}{du} = ?$

8 函數 $f(x) = (x-1)^2(x-2)^3$ 的相對極大値與極小値分別是多少？

9 $x = e^t \sin t, y = e^t \cos t$，試求 $\frac{dy}{dx} = ?$

10 何謂「微積分基本定理」？有何重要性？

備考	試題隨卷繳交

考試科目	經濟學	所別	科管所乙	考試時間	4 月 18 日 [✓ 上] 下 午第 1 節 星期日

經濟學（乙）93

一、

（1） 請解釋以下名詞：（18%）
進入障礙，套牢，轉換成本，網路外部性，規模經濟，搭售

（2） 微軟一再投入重金以更新並擴充 WINDOW 系統軟體的功能，甚至要把 IE 瀏覽器也納入系統軟體的一部份。請用以上名詞解釋微軟採取這種策略行爲的原因。（12%）

二、請儘量輔以圖表或方程式來說明需求函數與供給函數是如何導出來的。（10%）

三、一群生產者（每人只生產一單位同質產品）的邊際成本曲線是 MC＝0.5Y，而一群消費者（每人只消費一單位）的邊際價值曲線是 MV＝100-Y 。

請問：（40%）

1、生產者及消費者都是價格的接受者時，市場均衡價格及成交量會是多少？

2、如果生產者者組成聯盟，成爲獨賣者；消費者毫無議價能力，但是獨賣者卻無法分辨個別的消費者，只能訂出一個價格，由消費者自行決定要買或不買。請問獨賣者會如何取價，需求量是多少？

3、如果消費者組成聯盟，成爲獨買者，但不能分辨個別生產者；而生產者毫無議價能力，請問獨買者會如何取價，需求量是多少？

4、如果生產者者組成聯盟，成爲獨佔的供給者，而消費者也組成聯盟，成爲獨買者；請問議價的空間何在？

四、何謂「市場失靈」？哪些因素會使得市場失靈？爲什麼？請分別說明之。（20%）

備考	試題隨卷繳交

考試科目	企業管理個案	所別	科管所(學士後乙組)	考試時間	4月18日 上[✓ 下]午第三節 星期日

試題總共包括四個個案，請充分作答並把握時間

個案一 華宇電腦公司

告別一同成長的惠普(當時爲康柏)後，2003 年是華宇在筆記型電腦(NB)製造產業最辛苦的 1 年。但是，近 1 年來陸陸續續已讓數張惠普新 NB 訂單從手中溜早的華宇，毅然決然願意在最後關鍵放棄攸關未來營運命脈的訂單，不但是量力而爲的做法，更勇於向國際 NB 大廠利用台灣 NB 廠商彼此廝殺坐收漁翁之利的策略「說不」的膽識。

或許華宇可能將因此在 NB 製造產業永無翻身的餘地，但在逆境中展現不「飢不擇食」的決心和風範，間接產生維持 NB 製造市場秩序的效益，至少可以讓國際 NB 大廠是從的其他 NB 製造業者以爲借鏡，而以退爲進的華宇，沉潛後蹲下再躍起所能達到的成就，將不會只是曇花一現。

事實上，華宇原先認爲即使惠普採取打開大門和所有 NB 業者都有合作機會的策略，基於雙方長期的革命情感，這款華宇最擅長低價消費性 NB 產品線和訂單，「照輪也該輪到他們」。

而且，華宇爲了配合惠普「高階機種低價搶奪市場」的策略，嚴重犧牲獲利，在 2002 年 3Q 的毛利遽降到 1.9%，創下「台灣 NB 業界新低」，被迫調降全年財測從原本的新台幣 20.08 億元降爲 3.04 億元，降幅高達 84.86%。

相反的，惠普同期獲利則高達 7.21 億美元，相較 2001 年同期的 2.38 億元，成長幅度超過 300%，充分展現合併後重整組織、精簡人事，和從供應商擠壓出來的利潤的成效，出現天壤之別的落差。

沒想到，惠普在最後關頭不僅無視於華宇的鞠躬盡瘁，更決定讓華宇死而後已，在明知華宇無法在價格成本上提出更誘人條件的情況下，依舊對參與訂單爭奪的廠商開出更低的價格要求，擺明就是要讓華宇知難而退，從 NB 供應商名單上剔除。

華宇擁有 300 多位和 NB 相關的研發工程師，銀行帳戶中更有新台幣 80 億元~100 億元左右的現金，雖然集團總戰力不如廣達、仁寶、英業達及緯創等主要競爭對手，但決不至於沒有能力在合理的情況下承接此訂單。

換句話說，台灣 NB 業者必須以華宇爲借鏡，因爲，只要國際 NB 大廠食髓知味，必定在其他廠商身上重施故技，在唯價格是問的產業環境下，任何合作關係和績效都不是重點，國際 NB 大廠不僅要在市場上賺錢，更不會讓供應商多得一毛錢，甚至從供應商身上獲利，因爲，台灣 NB 製造業者何其多，即使少 1 家還是有其他廠商願意隨之起舞。

(本文摘錄至電子時報,曾而汶特稿)

個案一問題 (25 分):

1. 華宇公司代表我國資訊電子業典型的代工業者(OEM、ODM)，請分析：公司以代工爲主要的業務型態時，分別有何可能的優勢與劣勢?
2. 華宇公司最後採取不「飢不擇食」的作法，你贊同嗎？爲什麼？你對該公司未來的發展策略有何較爲具體的建議？

備考	試題隨卷繳交

命題委員：　　(簽章) 93 年 4 月 5 日

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考試科目	企業管理個案	所別	科管所(學士後乙組)	考試時間	4月18日 星期日 上 [✓ 下]午第三節

個案二 The Pizza Distribution Olympics: A Question of Dough……

…the kind you spend as well as the kind you knead and spread in a pizza pan. Domino's Pizza Distribution Olympics was management's brain-storm for recognizing employee achievement and encouraging high, uniform work standards at the same time. This special event takes place every July and features employee competition in events ranging from forming dough（麵團） balls and driving pizza trucks to slicing vegetables and balancing an accounting ledger.

The Olympics began as a way of recognizing the essential, but often unsung, efforts of Domino's subsidiary, Domino's Pizza Distribution.
This unit was formed to provide Domino's retail stores worldwide with vegetables, toppings, napkins, uniforms—and, of course, dough. However, Domino's franchisees aren't obligated to buy from the subsidiary. That's why the subsidiary works hard to please the stores it serves.

Domino's founder Tom Monaghan once called the Distribution unit his "secret weapon" because of its contribution to Domino's success. However, keeping employee morale high was difficult, in part because the subsidiary's work was virtually unknown outside the company. However, Valerie Russell, an accountant at company headquarters, believed participation in the Olympics would not only highlight the importance of every individual's job but also act as a means of monitoring and improving work standards by making performance competitive.
The three-day Olympics event is now company wide. Each department in the Distribution subsidiary holds competitions to qualify team members for the Olympics. The local winners are flown to headquarters to compete for valuable prizes, such as cash, rings, and vacations. Contestants have a good time and, at the same time, they demonstrate work practices that lead to faster or more efficient performance. After the competition, Domino's managers meet with the champions to discuss how the winning procedures, methods, and techniques can help improve every-one's job performance.

The dough event, for example, yielded unexpected dividends. Management observed that contestants were using a number of techniques and achieving varying results when they prepared pizza dough. So the Domino's managers picked the brains of the best dough makers to create a manual detailing the specifics of dough production. This manual helps employees in every Domino's unit make good dough every time by following the procedures outlined by the chain's winning dough makers.

Dough makers haven't been the only personnel inspired to better performance.

備考	試題隨卷繳交

命題委員：

（簽章） 93 年 4 月 5 日

命題紙使用說明：1.試題將用原件印製，敬請使用黑色墨水正楷書寫或打字（紅色不能製版請勿使用）。
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考試科目	企業管理個案	所別	科管所（學士後乙組）	考試時間	4月18日 星期日 上[✓ 下]午第三節

Also rising to the occasion was the Florida-based truck driver who times himself whenever he loads his truck (and the many others like him who were stimulated to make a special effort by special recognition).

個案二問題 （20分）：

1. Domino's budgets more than $1 million yearly for the games. What does the company gain in return?
2. What effect does the pooling of expertise have on employee morale and performance?
3. Do the Pizza Olympics appeal to lower-level or higher-level employee needs? Why do you think so?

個案三 「文化改變」的力量

遠傳電信策略暨行銷事業部副總經理何永生曾在奧美演講上提到，他認爲各家品牌的運作，優劣層次不同，運作在最高層次上的品牌，最明顯的特色是他們都具有「文化改變」(Cultural Changing)的強大影響力。翻開 2003 年<<Business Week >>全球最佳品牌排行(2003 Best Global Brands Scoreboard)，可以發現這個說法立刻得到具體的驗證。

可口可樂帶妳偷窺名人

排名世界第一的品牌是可口可樂。可口可樂甚或百事可樂，長期以來，幾乎就是美國通俗文化的催化者之一。美國 2003 年可口可樂的新廣告，安排一系列名人「真實生活」演出，受到新一代年輕人的熱烈歡迎。其中一個廣告，描述性感可人的潘尼洛普克魯斯(Penelope Cruise)漫步走入餐廳，在眾目睽睽之下，旋開可樂，大剌剌地喝下。喝完之後，還打了一個大嗝，並害羞地笑了。

在另一個廣告裡，Courtney Cox(影集<<六人行>>的其中一個女主角)，在真實人生裡，在家居的場合中，甜甜地到了一杯可樂遞給自己真實生活中的先生。藉由這一連串廣告，可口可樂提供了一般人極少數能窺見名人真實生活的機會。這一廣告其實反映了或甚至創造了很重要的一個時代的氛圍，那就是，"Realness"—真實感覺。雪城大學電視文化中心總監 Robert Thompson 提到，在這個戰事不斷，經濟情況未明朗的不確定時間下，這個「真實感」的提出，來得正是時候。

有趣的是，如果我們比較全球品牌及亞洲品牌排行榜，會立即發現一個本質上的差異，全球前十名的品牌，例如可口可樂、麥當勞、迪士尼、NOKIA、萬寶路等，都是「改變文化」(Culture Changing)品牌，但是亞洲前十大的品牌，例如，國泰航空，Banyan Tree 飯店，李錦記等，都以「經驗」取勝。可見「文化改變」對亞洲品牌來說，尙是一塊未開發的淨土。

在台灣的品牌中，全心致力於品牌建造，及文化改變的，是韓國的三星電子(SAMSUNG Electronics)。

備考	試題隨卷繳交

命題委員： （簽章） 93 年 4 月 5 日

考試科目	企業管理個案	所別	科管所（學士後乙組）	考試時間	4月18日 星期日 上 [✓ 下] 午第三節

三星在廣告上，和電影<<Matrix Reloaded>>(駭客任務 2：重裝上陣)的結合，也是另一個「文化改變」的嘗試。在一次 CLSA 的訪談中，Eric B Kim，SAMSUNG 全球行銷領軍者，提到這部電影，他認爲它不只是一個票房高的科幻電影，它定義了我們這一代的文化現象，也代表了整個時代的風格、美學和思考，這也是三星產品極力想做到的。

這種「文化改變」的作法和哲學，對消費者的意涵是什麼？無庸置疑的是，如果你手持的手機，就是駭客任務中，真實世界和虛擬世界交界主要關口的那支手機，大概每次使用它時，都會以爲自己也是拯救世界完美無瑕的基努李維？！

(本文摘錄至陳倩如【2003.10.1】<u>數位時代</u>，p.102)

<u>個案三問題</u> (35 分):

1. 個案中提到:「亞洲前十大品牌（例如國泰航空、李錦記等）都以『經驗』取勝」，請說明這句話主要的含意。
2. 請分別從不同的觀點來剖析「文化」與「行銷」之間的可能關係。
3. 請問：什麼是「文化創意產業」？
4. 韓國三星電子在全球品牌的地位上已經很接近日本 SONY，請問：台灣的公司能否發展到接近三星的全球品牌地位？爲什麼？如果要達到此地位，你給台灣科技公司的主要建議爲何？
5. 請試著說明：如何估算出一家公司的品牌價值(Brand Equity)?

<u>個案四</u> 趨勢科技

1988 年於美國加州成立的趨勢科技，創業之初即專注於發展電腦病毒偵測技術、確保電腦系統運作安全。歷經 15 年的鍛鍊與發展，成爲全亞洲地區唯一擁有自有品牌、並銷售企業級防毒軟體整合系統、提供資訊內容安全解決方案的專業技術服務公司，並成功地進入國際市場，成爲全球數一數二的專業防毒軟體公司。

科技進步神速，資訊病毒的製造也越來越聰明，不斷地在寄生、變形，身爲電腦醫生的趨勢科技，深深明白電腦中毒的後果不堪設想，常常想盡辦法杜絕病毒，也爲了揪出毒瘤，從不間斷地進行沙盤推演，試圖給現代人資訊最好的保護。

基於此，趨勢科技在企業文化的營造上也以「創新」(Creative)爲第一精神指標，再加諸「溝通」(Communication)、「求變」(Chang)、「顧客」(Customer)以及「值得信賴」(Trustworthy)等四項指標，一點一滴爲顧客設想周到。

在創新上，不停駐的創新求變，使得趨勢科技得以持續創新開創電腦防毒和資訊安全的新興觀念，輔以日新月異的資訊科技來爲客戶解決各種層出不窮的電腦病毒以及容易藏污納垢的資訊安全問題。

在溝通上，爲了讓員工有效地創新，促使其瞭解趨勢的目標所在，凝聚員工的精神能量一直是趨勢科技整合內部能量、投身電腦病毒偵測級網路安全解決

備考	試題隨卷繳交

命題委員：

（簽章） 93 年 4 月 5 日

命題紙使用說明：1.試題將用原件印製，敬請使用黑色墨水正楷書寫或打字（紅色不能製版請勿使用）。
2.書寫時請勿超出格外，以免印製不清。

考試科目	企業管理個案	所 別	科管所（學士後乙組）	考試時間	4 月 18 日 星期 日 上 [✓ 下] 午第 三 節

方案研發的關鍵。

在求變上，要持續在資訊安全產業中搶得機先，必須打破資訊技術和市場快速改變的現況，趨勢科技時時要求依照技術、趨勢以及市場的最新資訊調整研發以及業務的方向。

在顧客上，接櫫「以客爲尊」的信念，接近顧客、服務顧客、提供顧客盡善盡美的電腦防毒與資訊安全解決方案。

在值得信賴上，也是已故客爲出發點，所以在趨勢科技的作法上以長期維持顧客購買意願已極維繫顧客忠誠度爲重要關鍵，要求員工將顧客的事當作是自己的事來看待。

隨著不斷地創新，趨勢科技全球營業收入項目也隨之逐步轉型有了重大改變。1996 年，趨勢科技研發的套裝個人電腦防毒軟體 PC-cillin 占趨勢科技全球總營業額 80%以上，伺服器防毒軟體、OEM/bundle 以及企業授權所佔之營業收入不到 20%，當中沒有任何營業收入來自客戶專屬技術服務。在經過多年的研究發展、不斷在技術上升級，在營運模式上追求轉型，2002 年趨勢科技已蛻變爲以總體電腦防毒系統及相關資訊安全解決技術服務的全方位資訊安全系統公司，其中全球所有整體防毒方案企業授權的總收入高達全公司營收的 60%、客戶專屬企業服務(Premium Support Program, PSP)全球營業額已達總營收的 18%，全球 OEM/Bundle 的營業額占總營收的 12%、而在 PC-cillin 產品上也向下調整爲總營業額的 10%。近 5 年來趨勢科技在營業額上每年平均有 30 至 40%的成長，甚至總營業額成長已經超過 4 倍以上。

趨勢科技爲了讓企業和個人用戶能夠對病毒的肆虐防範於未然，必提供最佳的服務，在「預防勝於治療」的前提之下，趨勢科技也加重了事前的預防策略來降低突發病毒所帶來嚴重損害和減輕善後處理的工作。在全方位照顧企業資訊的服務中，趨勢科技研發出企業安全防護策略(Enterprise Protection Strategy, EPS)擴充方案，以服務爲宗旨的全新觀念，其中包含病毒服務保證同意書(Virus Response Service Level Agreement, SLA)。

爲確保客戶使用產品以及受到的服務都是第一，趨勢科技積極追求世界及品質管理系統，在 2001 年趨勢科技全球 7 天 24 小時防毒研究及支援服務的 TreadLabs 順利通過 ISO9002 認證，另外亦是亞洲首家取得 ISO9002 認證的防毒軟體廠商。而在顧客服務方面，趨勢科技設置有 Corp Service Team、Core Team、PSP Team 由淺入深地解決顧客在病毒預防以及產品維護上的所有問題，發揮全方位完整的保護功能。回顧過去，展望未來，趨勢科技無疑都是世界舞台上一顆閃亮的明星。

（本文摘錄至楊苓欣【2003.11】能力雜誌，114-117 頁）

個案四問題（20 分）：

1.何以趨勢科技公司能夠成爲全球數一數二的專業防毒軟體公司？

2.趨勢科技公司與台灣一般的製造公司比較，在經營管理上可能有何異同？

備 考	試題隨卷繳交

命題委員： （簽章） 93 年 4 月 5 日

考試科目	管理個案	所別	科管所(碩士後組)	考試時間	4 月 18 日 星期日 上下午第 1 節

Question 1

1-1 How would you evaluate Team New Zealand's use of simulation in the design process? 20%

1-2 What are its advantages and disadvantages? 20%

1-3 How did their approach to simulation differ from that used by other syndicates? 20%

Question 2

2-1 Which yacht construction strategy should Team New Zealand follow? Why? 20%

2-1 How much improvement would you expect from each? 20%

Doug Peterson leaned back in his chair and twisted the cap off another Steinlager. The Wharf Cafe had grown crowded and smoky since the meeting had started. "We really have to get ourselves a proper conference room next time," he thought, as he stared out over a misty, gray Auckland harbor.

It was late May 1994. Peterson had been working on the design of New Zealand's 1995 America's Cup yacht for over a year. As lead designer, he had conceived the original concept and recruited the design team, which, for the first time, was making extensive use of sophisticated computer-aided design and simulation tools. Now, as the team assembled for its weekly review after the day's sailing, the time had come to commit to the construction of the new yacht.

Peterson pondered the decision they faced. The budget allowed for two yachts to be built; however, there were several strategies they could take with regard to their design. Should they build two yachts with *similar* hull and keel designs, so they could vary the details of the keel design and race them against each other to assess potential improvements? Should they build two yachts with hulls optimized for *different* sailing conditions? Or should they build one yacht now, but delay building the second, waiting till after another round of prototype tests, while they experimented with the first one on the water?

備考

The decision they made in the next hour would profoundly affect their chances of winning in San Diego and becoming only the second team in 145 years to win the Cup from the Americans.

THE AMERICA'S CUP

In 1851, the Royal Yacht Squadron of England offered a silver trophy, called the Hundred Guinea Mug, to the winner of a sailing race run around the Isle of Wight, a small island off the south coast. Open to all nations, the race attracted 15 English entries and only one foreign challenger—the eventual winner, America. The Hundred Guinea Mug thereafter became known as the America's Cup, in honor of its first winner, and when the last surviving owner of the victorious team donated it to the New York Yacht Club, it was decided that challengers from other countries should be allowed to compete for the trophy in a "friendly competition between foreign nations." The rules for these races were defined in a document called "The Deed of the Gift."

The first America's Cup challenge was held in 1870. Over the next 30 years, the American defenders successfully defended against teams from England, Scotland, Canada, and Ireland. At this time, participants were not limited in design, hence boats varied greatly in both size and power. However, since the European challengers were required by the rules to cross the stormy North Atlantic under their own sail power, their boats were often heavily built and slower than the Americans'. Races were often one-sided affairs, of little interest to spectators.

In 1920, the rules were changed to specify the use of J-class designs, enormous single-masted boats over 100 feet long, with masts 120 feet high and a crew of 40. While races became closer, ultimately, the results were the same. Between 1920 and 1937, the Americans made another four successful defenses. After a long break due to World War II, J-class boats were ruled too expensive, and a new 12-meter class was created, with 65-foot long hulls, 90-foot masts, and a crew of 11. The rules were changed so that challengers' boats could be transported to the race site by ship rather than having to sail. As designs converged, racing became even tighter. Even so, between 1958 and 1980, the Americans defended successfully another eight times.

In 1983, the longest winning streak in sports history—132 years—ended when the revolutionary Australia II, with a radical and controversial "winged keel," defeated Liberty, under the helmsmanship of Dennis Conner. In 1987, however, Conner regained the cup in Perth with Stars & Stripes, racing for the San Diego Yacht Club. The next year, a team from New Zealand, exploiting a clause in "The Deed of Gift," challenged Conner with a huge boat nicknamed "The Big One." Without time to redesign, Conner defended successfully with a 60-foot ultralight catamaran, the first use of a double-hull in the America's Cup.

In 1992, a new yacht class was defined for the lighter winds of San Diego. The International America's Cup Class (IACC) required boats of 75 feet in length, with 110-foot masts and a crew of 16. By using advanced materials, boats became lighter for their size, and hence faster in the light winds. While America 3 eventually defeated the Italian challenger in the final, the 1992 races were enormously expensive. The American defender built five boats, the Italian challenger four. Both spent over $60 million. It was decided in the future to reduce expenses; each team would be limited to only two boats, with further limits on the use of sails and other equipment.

The 1995 cup races would follow a round-robin format. First, the boats would be divided into two groups: the defenders, from the country of the current cup holders, and the challengers, from all other nations. The racing would then be divided into three parts. In the first, which will start in January, the challengers will race against each other for the right to enter the final (this will be called the Louis Vuitton Cup). In the second, which will run simultaneously with the first, yachts from the host country will race for the right to defend. Finally, in May, the winning challenger team will race against the winning defender team for the America's Cup. Boat designs will be allowed to evolve between each race, until the start of the final.

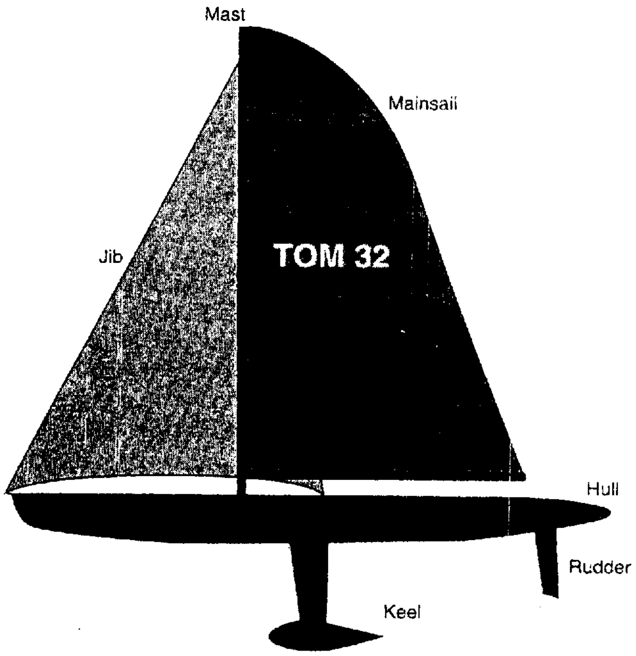
Typical time differences between first- and second-placed boats would usually be less than one minute.

THE DESIGN OF A RACING YACHT

The design of a present-day racing yacht comprises four essential elements—the hull, the keel, the mast, and the sails (see Exhibit 1). The objective of the design team is to produce a light boat with as low a drag factor as possible. The structure, however, must also have the strength and stability to cope with highly variable wind and sea conditions. To achieve this balance, teams rely heavily on the skills and experience of the lead designer to make many critical trade-offs during the design process.

The bulk of the initial design work focuses on the hull and keel, as these are on the critical path for the construction of the yacht. To develop these, designers have

EXHIBIT 1 Schematic of a Recent Racing Yacht



traditionally relied on what is known as the "tank-and-tunnel" process for getting feedback on performance. This process entails construction of a series of scaled-down physical prototypes which are tested in a wind tunnel and a towing tank (a large swimming pool equipped with a winch at one end, which tows the prototype down the middle) providing data on the amount of drag generated by a particular design.

During the initial stages of a typical yacht development, five to six physical prototypes are built at one-quarter scale (20 feet) and subject to testing in the wind tunnel and towing tank. Fabrication and testing of these prototypes takes several months and costs about $50,000 per prototype. Data on the performance of each of these designs are analyzed to assess relative performance characteristics and used to project potential design enhancements. A further set of prototypes is then built, and the whole process repeated. This series of prototype iterations typically occurs three or four times prior to freezing the design for construction. As Peterson explained:

> The tank-and-tunnel method is a design process where experimentation occurs in bursts. Every couple of months, you get back the results of your experiments. As a result, there is a limit to the number of design iterations you can perform. A typical project can rarely afford more than 20 prototypes, due to time and money constraints. In each design cycle, you have to rely on big gains in performance.

THE USE OF SIMULATION IN DESIGN

The design of the critical surfaces on a present-day racing yacht is a complex activity. The presence of many interactions means it is not easy to predict the effect of even small changes in the structure. The system is "chaotic," and predicting its behavior is much like trying to predict the weather. While traditional tank-and-tunnel design methods rely on experienced designers and informed trial and error to overcome such complexity, the advent of cheap computer hardware and automated design tools have led to rapid advances in the possibility of simulating designs.

Modern yacht design makes use of several tools to help automate the process. Among the most important are finite element analysis (FEA), a tool which analyzes the structural characteristics of a design; computational fluid dynamics (CFD) programs, which help simulate the flow of water over the yacht's critical surfaces; and velocity prediction programs (VPPs), which predict how fast a particular design will be in a given set of wind and sea conditions.

CFD programs were originally developed for the aerospace industry, traditionally being used to model the flow of air over an aircraft's control surfaces. The software is "panel-based," the structure first being "broken up" into many small panels, each of which is represented by a set of mathematical equations. The program links these panels together to form a model of the complete design, then solves a set of equations governed by fluid mechanics theory to calculate the pressures and flows at the surface. While CFD had been around since the 1960s, its application to yacht design was a recent phenomenon as the teams began design work for the 1995 America's Cup. In its initial applications, it had met with only limited success, and opinions were mixed as to its usefulness.

Advantages of Simulation

The major advantages of simulation over traditional design methods fall into three main areas. It is cheaper and faster than constructing physical prototypes, it generates more insight into why particular designs are better or worse than others, and it avoids problems associated with "scaling up" the design from a physical prototype to the real world.

The primary advantage of simulation is in its speed and cost. While programs often require a significant amount of computing memory and processing power, once a basic design has been configured, design iterations can be run in a matter of hours, at little cost. The only limitation on how many iterations can be conducted relates to the amount of computer power available and, more important, the capacity of the design team to interpret results. In general, the bottleneck becomes a team's ability to generate and evaluate new configurations, not its ability to test them.

Another important advantage of simulation is that it establishes an understanding of the trade-offs involved with alternative design choices. Although tank-and-tunnel methods give a good indication of the overall performance of a design, they do not help the designer interpret why one design is performing better than another. CFD, by comparison, can show the pressure distributions and flows around a hull or keel which generate the drag produced by a given design.

A final advantage of simulation is that it avoids the problems of "scale-up." This occurs when the use of scaled-down models introduces distortions which affect the accuracy of test results. For example, certain types of drag, generated by the chaotic nature of a fluid flowing over a surface, are very sensitive to scale; hence, results from reduced-scale physical models are likely to be inaccurate. The use of simulation avoids such a bias.

Drawbacks of Simulation

Although simulation has many advantages over tank-and-tunnel tests, these tools are complementary nevertheless. As Peterson emphasized, "Even with all the simulation in the world, no one is going to commit $3 million to a yacht without towing it down a tank first!" Physical prototypes are used extensively early in the design process to set the basic parameters of the hull and keel. Once these have been defined, simulation is used to help optimize their shape.

The importance of simulation is greatly increased once the hull and keel have been built. CFD can be used to substantially improve the performance of the yacht through the design of aerodynamic wings which attach to the bulb at the bottom of the keel (the lead weight which gives a yacht its stability). In the run-up to a major race program, extensive testing and refinement of these appendages occurs, driven by the results of simulating different designs. These changes can lead to substantial improvements in performance.

Ultimately, however, all of these tools are only as good as the designer in whose hands they are placed. The lead designer is responsible for putting together the initial concept, without which no amount of simulation will yield a good design. Also in charge of directing the experimentation strategy, the designer is the person who says "what to try next." The concept design and experimentation strategy together provide critical "stakes in the ground" and a sense of direction—activities for which automated design tools provide little help. As Peterson noted:

> The CFD program can't design a yacht from scratch without conceptual input. It doesn't know what parameters it should be optimizing. Consider designing a golf ball to fly as far as possible off the tee. The computer won't tell you the ball should have dimples, but if you specify this as a design parameter, it will find the optimal dimple pattern and density for you.

TEAM NEW ZEALAND

During May 1993, general manager Peter Blake began putting together the team of people who would work together for over two years in an effort to win the America's Cup. The Team New Zealand syndicate comprised about 50 people, with activities split between team management, design and construction, and the crew, skippered by Olympic Gold medalist Russell Coutts (see Exhibit 2).

The budget for the syndicate, raised from corporate sponsors in New Zealand, was $20 million. While comparable to the budgets of other teams, Team New Zealand had decided to build two boats, rather than one, due to the experimental benefits this would give them during the testing period. Given the full cost of a boat, mast, keel, and sail program was around $3 million to $4 million, it was clear from the start that the money for other resources would be severely limited. The team would need to be small, focused, and highly motivated, with everyone adopting multiple roles.

Blake's philosophy in running the team was to have all the critical people on board from the beginning. On 24th May 1993, the team assembled for the first time. Rather than dive straight into the detail of design and crew training, they spent the first three weeks working together with an external consultant to outline the mission for the team and a vision of how they would work together. Peterson described the process:

> We spent a lot of time going over why certain teams had won or lost in the past. What we found was that unsuccessful efforts were often driven by one or two personalities, be they designer-driven, skipper-driven, or owner-driven. Suc-

EXHIBIT 2 Team New Zealand Syndicate: Key Staff Members

Syndicate head:	Peter Blake
Yacht Club:	Royal New Zealand Yacht Squadron
Syndicate budget:	Estimated $20 million
Team sponsors:	ENZA (New Zealand Apple and Pear Board) Lion Nathan (Steinlager) Lotteries Commission Television New Zealand Toyota New Zealand
Management	
Campaign public relations:	Alan Sefton
Campaign business manager:	Ross Blackman
Lead Crew	
Skipper:	Russell Coutts
Navigator:	Tom Schnackenberg
Afterguard:	Brad Butterworth Rick Dodson Murray Jones
Design Team	
Chief Designers	Doug Peterson Laurie Davidson
Computational dynamicist	David Egan
Aero/hydro dynamicist	Richard Karn
Performance analyst	Peter Jackson
Structures/weather	David Alan-Williams
Construction	
Construction chief	Tim Gurr
Structural experts	Wayne Smith Mike Drummond Chris Mitchell Neil Wilkinson

> cessful teams were truly "managed," not dominated by one voice. Hence we wanted to run the syndicate in a democratic fashion. When we had differences of opinion on which direction to go, we'd put it to a vote. One of the most important outputs of the three weeks was the mission statement, which described the way that things would run. Above all, we stressed open communication and dissemination of knowledge, even to the extreme of running classes on yacht design and weather forecasting for anyone who was interested.

With the three-week "vision thing" behind them, the staff at last assumed their more traditional roles. The crew began training, using the yachts which had been built for the last America's Cup, and the design team began work on the concepts for the new design.

The Design Process

Doug Peterson was appointed to lead the design team. An American by birth, Peterson had extensive experience with designing boats and racing yachts. Peterson had no formal design or engineering training, but had been designing boats for as long as he could remember: "This is what I have always done. I can remember when I was in high school, I would spend all my time designing boats on pieces of scrap paper instead of paying attention in class." About 30 years and thousands of designs later, he was considered to be one of the world's leading yacht designers. His latest achievement was the design of the America 3 boat, the America's Cup winner in 1992. Peterson was given responsibility for developing the overall design concept for the Team New Zealand boat, specifying test models, analyzing results, and developing construction plans.

As the design team planned to make extensive use of automated design and simulation tools, Peterson assembled a mix of experienced yacht designers and simulation experts. Among them, Dave Egan was recruited to run the design simulations. Egan's appointment brought to the team prior experience in simulating yacht designs and a working knowledge of the required computer hardware, having previously been a sales agent for Silicon Graphics.

The design was initially driven by Peterson, who defined the initial boat concept and specified an implementation plan. Peterson drew upon the knowledge he had accumulated with the America 3 team to put his first thoughts to paper. Given America 3 had built five boats, each of which was significantly different in design, he had a lot of experience to help him. During the design process, the America 3 team had conducted over 65 prototype tests in the wind tunnel alone.

Egan's first job was to code this concept design into a geometry model for the simulation program, providing a baseline for performance. With this accomplished, design iterations and performance simulations began in November 1993. The initial simulations focused primarily on the design of the hull, with relatively simple keel variations. The team would have to commit to the hull design in May 1994, in order for construction to begin.

The Simulation Effort

Running CFD required substantial amounts of computer power. For example, to simulate the keel required coding 13,000 individual panels as part of the modeling program, creating data files of 6 to 8 gigabytes in size. While several syndicates were using similar analytical programs, the resources available to them and strategies they followed differed considerably.

Most syndicates had lined up large corporations to help with the task, allowing processing to be performed on the largest and latest supercomputers. Young America, for example, had over a million dollars of computer time available to them, through a partnership that included both Cray and Boeing. Boeing ran the design simulations on Cray supercomputers based in their headquarters in Seattle, using advanced CFD software developed for their aerospace needs. These machines were among the world's fastest computers, each costing several million dollars. Every few weeks, the Boeing engineers would run large batches of simulations and feed back their results to the Young America designers in San Diego. This allowed them to test a massive number of experimental designs.

The strategy adopted by Team New Zealand reflected the resource constraints presented by the budget. The team decided to use a small network of workstations which could be operated locally. Given the poor history CFD simulation had in yacht design, Egan was given less than $100,000 to cover personnel, hardware, and software. As he recalls:

> The early days of the project were a constant challenge to find resources. We were running around companies looking for computer time. At one, we managed to grab a 16 processor Challenge computer for a month prior to its being commissioned. The MIS guy never knew what happened! Then we gained access to a SunSparc2 workstation. Soon, however, the rising number of design iterations we needed to explore began to exceed its capacity.

As luck would have it, during Christmas 1993, Jim Clark, the CEO of Silicon Graphics, was in New Zealand having his yacht refitted. A keen sailor, Clark had invited several members of the team aboard his yacht. Over dinner, as he learned of their predicament, he immediately offered the INDY workstation installed in his yacht for the team to use. As Egan explains:

> Making contact with Jim was extremely timely. Although we declined the offer of his waterproof INDY, he did put us in touch with the local SGI office. They gave us access to the spare cycles on their demonstration machines, a four-processor Challenge server, and a couple of workstations.

The involvement of Silicon Graphics in the project grew with time. The company eventually became a sponsor of the team and lent a lot of computing equipment to the effort. This effectively increased the syndicate's simulation budget significantly. With a combination of workstations, the team could now simulate a new design every two or three hours. It gave the team immediate access to experimentation as the equipment was located a few feet from the dock. Egan emphasized the benefits of this approach compared with the tank-and-tunnel tests:

> Instead of relying on a few big leaps, we had the ability to continually design, test, and refine our ideas. The team would often hold informal discussions on design issues, sketch some schematics on the back of a beer mat, and ask me to run the numbers. Using traditional design methods would have meant waiting months for results, and by that time, our thinking would have evolved so much that the reason for the experiment would long since have been forgotten.
>
> We considered the crew our customers, in charge of what went into the design. They needed to drive the process. By having a computing strategy based upon local workstations, we had the ability to display results of simulations to them using flow-fill graphics. How we demonstrated the difference between two designs turned out to be a powerful marketing tool to help convince the crew of the benefits.

Team New Zealand's approach to simulation was extremely practical, heavily influenced by Peterson's experience. As he explained:

> Dave [Egan] was very realistic on the uses and limitations of CFD. In practice, if you start with a bad design, simulation won't get you anywhere near a good one. Some of the other syndicates let CFD drive their process. The Australians, for example, had some really deep simulation experts, and see where that got them.[1] At the end of the day, the real performance advantage is in the initial design. Everything else from there on in is just incremental improvement.
>
> Take the velocity prediction program. Trying to work out how the sails will perform is an extremely unreliable science. There's so much variability in the air flow. I told them to tweak it until they got the answer I expected; then we looked at the coefficients to see if they looked reasonable. In the end, it doesn't matter. All you're looking at is the differences between alternative designs. No one really believes we can accurately predict the time we'll put up over the course in San Diego.

During the six months between November 1993 and May 1994, the team cycled through building physical prototypes for tank-and-tunnel testing three times, building 14 scaled-down models. The first set of prototypes provided a performance baseline for the initial concept, allowing the team to parameterize the velocity prediction program and establish an estimate of the time around the

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[1] The Australian boat sank in one of the early trials while racing against Team New Zealand.

course in San Diego. For the second and third set of prototypes, Peterson attempted to improve upon the initial design using a combination of experience and the flow-fill pictures generated by the CFD program. The improvements were significant, with the best prototype from the third set of tests bettering the time of the initial concept design by over two minutes. Egan described the situation as of early May:

> We were emerging with a robust design for the hull and keel. We had reduced the drag considerably over the concept design, but now, each new prototype was giving us less and less improvement. The third set of prototype tests, which we'd just got back, produced less than half the improvement of the second. There was a strong argument that the most improvement potential was now in the keel appendages, where a lot of enhancements can be made through the design and placement of the wings. To run those experiments, however, you have to put a real yacht in the water.

Testing of the actual boat in the water would be combined with CFD simulation of the keel. The two would have to be used together, since historically only about a third of the changes suggested by CFD resulted in "real" improvements to the design.

"TWO BOATS, OR NOT TWO BOATS, THAT IS THE QUESTION"

In late May 1994, the syndicate was faced with a major decision. Construction of the first yacht was planned to begin next month for an August delivery (boat construction took about two months). This would leave about four months for travel to San Diego, testing, and improvements before racing was to begin in January. However, the initial budget had provided money for two boats, and there were several theories on how to get the best value from the second one.

One option was to commit to building two yachts now for delivery in August. This way, the yachts could be used in combination to conduct test iterations on the keel wings. Another option was to build only one yacht now, use this to begin testing different keel wings, and meanwhile conduct another round of prototype testing on the basic hull and keel design. The second boat could then be built just prior to the start of the qualifying competition in January.

Building two boats now would allow Team New Zealand to put two boats in the water at the same time. Egan articulated the perceived logic behind a two-boat testing program:

> The two-boat testing philosophy is driven by the fact that the sea is a noisy environment in which to run experiments. If we build two yachts of similar design, we gain the ability to run better experiments. We can put two keels with different wing designs on each boat, race them, and see how much difference there is. Then we can swap the keels and make sure the results hold for the other boat and crew. This way, there is no argument over whether the wind or sea conditions affected the results. The problem is especially relevant, given the improvements that come from changes to the keel wings are relatively small, in the order of two or three seconds over the whole course. Detecting these differences in noisy conditions is extremely difficult. Just a minor change in wind speed between two trials can easily swamp the effect of a design change.

In the past, teams using a two-boat testing program had shown that it was possible to run and verify the performance of a different keel wing design practically every 24 hours, particularly if the two boats were identical. During the day, while the crew were on the water, the simulation team would analyze hundreds of potential improvements to the keel appendages and select one or two which appeared most promising. Overnight, the construction team would work on the new designs and have them ready to sail the next morning. When the crew arrived, they would take the boats racing to verify whether the design changes produced real improvements.

With only one boat, alternative keel designs had to be removed and fitted during the sailing day. If conditions changed, the crew would often have to sail each design a number of times to identify which was better. As a result, verifying the results of design changes was slower than with two boats. Therefore, some argued that the differences in improvement speed between one- and two-boat testing would soon add up.

Building only one boat now traded the benefits of rapid feedback inherent in a two-boat testing process in favor of another cycle of testing prior to committing to the second yacht. Proponents of this approach argued that although the improvement potential in the basic design of the hull and keel had diminished, another cycle of tank-and-tunnel tests was still attractive. At the same time, running experiments with different keel appendages, even with only one boat, would still produce significant design enhancements. In combination, these two activities would yield greater overall improvement to the design and in addition would give the team the flexibility of building the second boat later in the development cycle. Building two boats now, they argued, was a waste of money and opportunity, particularly if these were identical.

Team New Zealand were not alone in having a budget big enough for two boats. As they tapped the sailing grapevine, however, other syndicates were taking diverse approaches.

The Japanese syndicate had decided to stagger the construction of their boats, opting to conduct another round of prototype tests before committing to the second one.

The leading Australian syndicate was building two boats simultaneously, but each was of very different design.

None of the three American defenders had decided to build two boats, despite having budgets of similar size to that of the New Zealand team. They had spent the money on other items, including more prototypes and iterations for tank-and-tunnel testing.

Team New Zealand's decision boiled down to three basic options: building two identical boats now; building two different boats now, perhaps one following one of Peterson's more aggressive concepts that hadn't made it to the wind tunnel yet; and building one boat now and one boat after some additional testing.