License valuation in the aerospace industry:
A real options approach

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Abstract

This paper discusses a practical case application of real options applied to license valuation in the aerospace maintenance, repair, and overhaul industry. After categorizing the available licensing opportunities of the firm, four distinct licensing classes are identified: traditional delay licenses, contingent investment licenses, licenses with cost uncertainties, and indefinite delay licenses. Due to the varying nature of the classes, accepted real option valuation techniques are applied to include the European call, dual asset, exchange, and perpetual option. Appropriate sensitivity analyses and discussion for each license class provide guidelines for decision-making. In general, it is shown that the real options framework captures value overlooked by discounted cash flow approaches.

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1. Introduction

Corporate planners may employ numerous evaluation tools to aid in the capital investment decision. Traditional techniques include payback period, internal rate of return, and net present value. Although useful for many applications, these techniques do not explicitly value the options embedded in some planning scenarios. Implicitly, they view the decision environment as static and assume that once a project is initiated, its basic components will remain unchanged. Management’s flexibility to delay,
abandon, or contract investment creates a dynamic decision environment necessitating the development of appropriate valuation tools. One such tool to value irreversible investments under uncertainty applies option pricing theory to real assets—commonly referred to as real options (e.g., Dixit & Pindyck, 1994; Trigeorgis, 1996).

Under the real options framework, any corporate decision to invest or divest in assets is simply viewed as an option. Firms have the right but not the obligation to invest, analogous to financial call or put options on a traded security. Applications of real options can be found in numerous areas to include manufacturing, inventory, natural resources, research and development, strategic decisions, technology, and stock valuation. In a recent survey of 4400 firms ranging in size and business practice, Graham and Harvey (2001) found that 27% of survey participants have implemented a real options framework to address their capital budgeting decisions.

From a modeling perspective, real options valuation methods have tended to follow financial option pricing techniques. The Black and Scholes (1973) and Merton (1973) models are used to value simple real option scenarios such as delay decisions, research and development, licenses, patents, growth opportunities, and abandonment scenarios. Additionally in 1979, Cox, Ross, and Rubinstein (1979) developed a binomial discrete-time option valuation technique that has gained similar popularity to value real options due to its intuitive nature, ease of implementation, and wide applicability to handle a variety of option attributes. Other closed-form equations originally developed to value financial options include: (1) Margrabe (1978) developed a model to price the option to exchange one asset. For real options analyses, the Margrabe model is used to value options with stochastic investment costs and benefits. (2) Geske (1979) developed a model to value compound options assuming deterministic exercise prices. The Geske model lends itself well for valuing contingent investment decisions. (3) Carr (1988) developed a model to compound exchange options. In a real options context, the Carr model values contingent investment decisions with stochastic investment costs and benefits.

The application of these real options methods has found its way into key business segments. Texaco and BP Amoco use real options as a gauge to value unexplored oil fields. As noted in Coy (1999), Anadarko Petroleum used an option’s framework to outbid competitors for a tract of land in the Gulf of Mexico. Hewlett-Packard used real options to help match supply with demand for its printers to save costs on over-customizing at its manufacturing facility. The Tennessee Valley Authority used real options in a 1994 decision to contract out for 2000 MW of power instead of building its own plants. New England Electric used options pricing to defer investing in a $52 million hydropower turbines project for one of its plants in Vermont. Airbus Industry uses options analysis to value contractual options with purchasers of its aircraft; in essence, an airline can pay a premium to lock in a price to pay for an aircraft, versus waiting and then paying the “going” rate for that aircraft. Intel Corp and Toshiba Corp use real options tools to help in the negotiating process of valuing licenses. Cadence Design Systems Inc. uses real options to set a minimum floor for a licensing agreement for its electronic design products.

This paper documents a practical case application of real options applied to license valuation in the aerospace maintenance, repair, and overhaul industry. The firm, Fairchild Fasteners, was interested in conducting an exploratory study to investigate the feasibility of applying options pricing theory to value strategic licensing opportunities. Given air travel demand uncertainty, increased competition, and large irreversible investment decisions, Fairchild Fasteners believed it needed to apply contemporary theories to successfully navigate the dynamic decision environment. This paper summarizes the initial efforts of this firm to value numerous licensing scenarios via real options frameworks.
Fairchild Fasteners identified several representative licensing scenarios within its manufacturing scope. We then categorized licenses by key attributes. As with any real world application, simplifying assumptions were necessary in order to apply known valuation techniques to achieve tractable results. We believed these assumptions did not lessen the importance of the real options analysis, as these same assumptions were applied under the firm’s traditional capital budgeting approaches. After reviewing the licensing attributes, four licensing classes emerged: traditional delay licenses, contingent investment licenses, licenses with cost uncertainties, and indefinite delay licenses. Each of these license classes is briefly described and placed within the appropriate real options framework. Then, the relevant valuation model is employed with appropriate sensitivity analyses and discussion.

The rest of the paper is organized as follows. Section 2 provides a brief description of the licensing opportunities in the aerospace maintenance, repair, and overhaul industry. Section 3 frames the four licensing classes as real options, values representative licenses, performs appropriate sensitivity analysis, and provides relevant discussion. Section 4 provides key insights and concluding remarks.

2. MRO licensing background

Utilizing real data provided by a firm in the aerospace maintenance, repair, and overhaul (MRO) industry, this paper values parts manufacturing approval (PMA) licenses. MRO activities refer to the maintenance functions required to sustain an active aircraft fleet. The amount of maintenance required is directly related to the total number and usage of active aircraft (i.e. the greater the air travel, the greater the maintenance demand, and the greater the MRO market). The firm under consideration produces over 1 million parts per day for over 1000 customers worldwide and is a global manufacturer of aerospace mechanical fasteners. A key business segment for this firm involves its PMA licenses. PMA licenses were enacted by the Federal Aviation Administration (FAA) for two purposes: (1) they monitor the quality of MRO replacement or modification parts for type-certified aircraft and (2) they ensure a supply of MRO parts for all aircraft. In a recent survey conducted by A.T. Kearney’s Aerospace and Defense Practice (e.g., Dubois, 2003), 96% of MRO respondents believed PMA parts to be among the top 10 issues facing the aerospace industry today.

In general, there are two suppliers of MRO parts to the maintenance end user—the original equipment manufacturers (OEM) and independents. End users are broadly defined as the airlines, military depots, and related service providers requiring parts for aircraft maintenance. The OEMs are firms that initially designed, manufactured, and sold parts for new aircraft. Obviously, the OEMs have established relationships in the industry and are aerospace’s key players including Boeing, Northrop Grumman, and Lockheed-Martin. The FAA does not require OEMs to acquire PMA licenses to sell their MRO parts. In contrast, the independents are usually firms in a niche area that may provide MRO parts, only after obtaining a PMA license. Any independent applying for a PMA license will incur irreversible expenditures in marketing, reverse engineering, and FAA testing fees.

OEMs and PMA independents fiercely compete for the right to sell the same parts to the same end users. Consider that the end user pays 30% less for a PMA part versus its OEM counterpart. However, even with the discount, some end users will not purchase the PMA part, and strictly use OEM parts. This

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1 The FAA lists all commercial and military aircraft as type certified aircraft.
is analogous to consumers purchasing name brand products versus their generic alternatives. Consequently, the PMA suppliers are operating on tighter profit margins versus the OEM, and the uncertainty associated with branding. Additionally, OEMs resist working with PMA firms by not supplying them part blueprints and engaging in price wars. When a PMA company introduces a part that competes with an OEM part, the OEM reduces its prices in order to mitigate market share loss and possibly drive the PMA supplier out. Additional complexity is added because the PMA system provides a path for PMA suppliers to eventually become an OEM themselves. For example, the PMA firm Superior licensed so many parts for the XP360 engine that it eventually had enough to assemble entire engines themselves. Finally, in addition to independent PMA suppliers, OEMs like Boeing and Lockheed-Martin are active in the MRO market and aggressively surveying the PMA landscape. For example, Lockheed-Martin had new design and production sales of $30 billion in comparison to its MRO sales of $29 billion in 2000 (e.g., Anderson, 2001). In order to grow their MRO revenues, OEMs may consider getting into the PMA business by pursuing other OEM competitor’s parts. All of these uncertainties and barriers need to be coupled with the forecasted 57% increase in worldwide fleet size to 24,481 by the year 2013.

In addition to the competitive MRO market, firms must also contend with uncertainty in market demand for air travel. The estimated value of the MRO market today is $44 billion, not including aircraft less than 19,000 lb, spares, and inventory (e.g., Koblish, 2003). Approximately 82% (or $36.1 billion) of the MRO industry is tied to the 15,583 active commercial aircraft, with military jets comprising the remaining percentage. An increase in air travel demand leads to an increase in the MRO market size, demand for replacement parts, and the value of being able to supply the replacement parts via a PMA license. Unfortunately, the reverse is also true. Consider the fact that 2100 aircraft have been retired and another 2000 aircraft have entered temporary storage since the catastrophic events of September 2001. These events have directly impacted the airline industry and the MRO market. Fig. 1 shows the U.S. airline industry earnings from the years 1990 to 2002 that serve as a proxy for air travel demand. As the figure suggests, the wide variations in airline revenues have directly impacted MRO activities. The annual MRO market size for the years 2000–2003 has been respectively $39.7, $42.2, $37.8, and $36.1 billion. These are considerable variations considering the fixed investment nature of aircraft.

Given the uncertainty in air travel demand, competition, and an increasing fleet size, developing a strategic plan to invest in PMA licenses is becoming a top priority for MRO participants. There are over 245,000 PMA part entries and 1920 unique PMA license holders. Developing methodologies and tools to evaluate worthy PMA licenses is critical to the survival of MRO independents. This paper
recommends a real options framework to value these PMA licenses. To the authors’ knowledge, the efforts presented in this paper are unique to the MRO industry and PMA licensing valuation.

3. Real options valuation

Obtaining a PMA license can be a costly endeavor due to the expenditures in marketing, reverse engineering, and FAA testing costs, and the irreversible capital outlays in equipment and processes once a PMA license is approved.\(^2\) Unfortunately, valuing many PMA opportunities utilizing discounted cash flow approaches yields little, as the PMA costs to obtain the license usually outweigh any estimated benefits on a present value basis. This is frustrating for many PMA independents because their gut instincts tell them some PMA parts are worth pursuing. In order to capture the strategic nature of acquiring the PMA license, it may be worthwhile to view the investment decision from a real options perspective.

3.1. Simple real options framework

Consider the PMA licensing process depicted in Fig. 2. The present value of PMA costs to acquire the license, \(C_A\), may be viewed as the option premium. The average licensing process takes \(T=2\) years to complete before the firm has an approved PMA license. Thus, when the firm expends \(C_A\), it acquires the right, but not the obligation to invest in equipment in year 2 to manufacture and sell the part. Even though the license is technically valid for an indefinite period of time, the firm is interested in the PMA license value assuming production in year 2. Thus, the real option value is really a lower bound estimate

\(^2\) Although there is some chance the aerospace firms can be denied a PMA license, most firms who proceed with a PMA license only do so when they are confident they will receive the license. Therefore, for the purpose of our analysis we ignore any risks associated with not obtaining a license.
of the license’s worth. The year 2 capital expenditure, \( I \), may be viewed as the exercise price of the real call option. If and when the firm invests \( I \), it then receives the underlying asset value, \( V_T \), which is the present value of future cash inflows from the PMA part of interest. Consequently, the payoff to the PMA license today may be expressed as the flexible net present value (FNPV) composed of the actual option premium, \( C_A \), and the theoretical worth of the option, \( C_0 \), calculated using an appropriate arbitrage-free pricing technique. In other words,

\[
\text{FNPV} = C_0 - C_A.
\]

From a decision-making perspective, the firm will invest if \( C_0 > C_A \). If the actual amount the firm pays today to acquire the option is less than the theoretical option premium, then the firm is acquiring value at a discount. One final point should be discussed. The \( C_A \) is a cost that is not impacted by market fluctuations because it represents costs unique to the firm in reverse engineering and preset FAA testing fees. As such, the PMA provider is actually using the market-based real options framework to value the firm specific actual option premium. Although similar in nature to other real options applications, this subtle difference should be pointed out. In contrast, a firm in the natural resource industry valuing a drilling license on property is actually using the real options framework to value \( C_A \) that is exogenously determined.

The investment in \( C_A \) may be viewed as a European call (or growth) option on a futures contract where the futures price is equal to the present value of the PMA part cash inflows, \( V_T \), at time \( T \) with exercise price \( I \) (e.g., Kemna, 1993). Assuming arbitrage-free valuation, the risk-neutral pricing approach derived for financial options is considered appropriate for valuing options on real assets (e.g., Birge & Zhang, 1999; Kamrad & Ernst, 2001; Mason & Merton, 1985; Trigeorgis, 1993). Thus, the theoretical worth of the option today may be determined using the standard European call option on a futures contract given in Black (1976):

\[
C_0 = e^{-rT} \left[ V_T N(d_1) - IN(d_2) \right] \tag{1}
\]

where \( d_1 = \frac{\ln(V_T/I) + 0.5\sigma^2T}{\sigma\sqrt{T}} \), \( d_2 = d_1 - \sigma\sqrt{T} \), \( V_T \)= present value of the PMA part cash inflows in year 2, \( I \)= investment outlay in year 2, \( \sigma \)=volatility of the rate of change of the PMA cash inflows, \( r \)=riskless rate of interest, \( N(\cdot) \)=univariate normal distribution function.

Table 1 utilizes Eq. (1) to value three of the licensing opportunities available to this firm. For the option’s analysis, \( r=4\% \), \( \sigma=22\% \), and \( T=2 \) years. The volatility is an unlevered estimate (e.g., Christie, 1982) that is calculated from the firm’s historical stock price volatility and its implied volatility on its

\[\text{Table 1} \quad \text{Real options valuation of three PMA licenses}\]

<table>
<thead>
<tr>
<th>PMA license</th>
<th>( V_T )</th>
<th>( I )</th>
<th>( C_0 )</th>
<th>( C_A )</th>
<th>FNPV</th>
<th>Decision</th>
<th>NPV</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>485</td>
<td>409</td>
<td>93</td>
<td>70</td>
<td>$23</td>
<td>Accept</td>
<td>$42</td>
<td>Reject</td>
</tr>
<tr>
<td>B</td>
<td>496</td>
<td>443</td>
<td>82</td>
<td>61</td>
<td>$21</td>
<td>Accept</td>
<td>$56</td>
<td>Reject</td>
</tr>
<tr>
<td>C</td>
<td>386</td>
<td>392</td>
<td>42</td>
<td>58</td>
<td>$16</td>
<td>Reject</td>
<td>$97</td>
<td>Reject</td>
</tr>
</tbody>
</table>

For our application the use of Black’s formula for option contract is equivalent to using the Black–Scholes formula since \( V_T = S_0 e^{rT} \), where \( S_0 \) is the market value today of the completed project.

The values have been scaled to preserve Fairchild’s data, but the relative magnitudes do reflect the real data.
publicly traded option prices.\textsuperscript{5} For comparative purposes, the traditional net present value (NPV) is calculated by discounting $V_T$ at the firm’s risk-adjusted discount rate, $k=9\%$ compounded continuously. To be consistent with the option’s valuation, the exercise price is treated as deterministic and discounted at the risk-free rate of interest in the NPV calculation. For example, for license A the NPV is calculated as follows:

$$e^{-0.09*2485} - e^{-0.04*2409} - 70 = -\$42.$$ 

The real options framework recommends investing in licenses A and B because $C_0 > C_A$ and $\text{FNPV} > 0$, and not investing in license C because $\text{FNPV} < 0$. Note the contrast with the NPV values and the implied rejection decision for all three projects. Utilizing this straightforward valuation approach, the firm may evaluate its licenses and prioritize license acquisition based on FNPV maximization. In fact, this firm is confronted with literally hundreds of PMA licensing opportunities that fit within its manufacturing scope. As a first pass, maximizing FNPV provides a technique to prune the firm’s PMA licensing candidates and allows the firm to direct its resources to potentially profitable licenses.

Fig. 3 performs a sensitivity analysis on the key inputs for license A. The percentage change is the percent deviation from the baseline inputs provided in Table 1. Similar to any sensitivity analysis, the input of interest is varied while the other inputs remain unchanged. Because the inputs to a real options analysis are today’s best-guess estimates of benefits and costs, Fig. 3 provides useful information for decision-making. Consider the critical region on the plot that indicates the change in $V$ and $I$ that yield $\text{FNPV} < 0$. If estimates for $V$ are 10\% less or $I$ are 11\% more than currently projected, then investing in license A would not be recommended. If the firm is uncomfortable with this critical range, then it should postpone investment in the license until further information is obtained. Note that the real options framework provides a technique to gauge investment worthiness, similar to net present value. Because the inputs to the real options analysis are estimates, the options value should not be used as an absolute

\textsuperscript{5} With any option pricing model, the key element to the valuing the option is volatility. The problem with real options is that the underlying asset (the project) is non-traded asset, which makes finding an estimate for the volatility difficult. For our analysis, we use both the unlevered historical stock price volatility and the unlevered implied volatility for a two year call option written on the company’s stock price. At first glance, this may seem questionable for the uncertainty in the stock price is a function of the risk inherent in a portfolio of projects the firm has undertaken. The volatility, however, could be a reasonable proxy if the project under consideration resembles an average asset in the firm’s portfolio. In this sense, the volatility of the portfolio would match the uncertainty in the project one to one.
measure. Instead, the real options approach provides a technique to quantify the expected worth of the license by capturing the inherent flexibility of the licensing scenario.

3.2. Dual asset framework

Many of the proposed PMA parts are correlated with one another. The equipment employed and information gathered from one part may be used to guide downstream decisions on alternative parts. For example, consider licenses D and E in Table 2. License E is contingent upon the successful implementation of license D. In other words, investment in license E cannot occur until license D has been successfully activated. To determine the economic value of this investment opportunity, this scenario is evaluated from several perspectives. First, traditional NPV is calculated on licenses D and E. Due to the time delay and licensing costs, the NPV is negative for both and investment is not recommended. Second, investment in license D is evaluated utilizing a European futures option framework via Eq. (1). The FNPV is also negative and investment is not advised. However, the futures options framework is unable to value the follow-on investment in license E, and it too undervalues the contingent licenses.

To frame the contingent investment, a dual correlated asset model is considered (see Fig. 4). Today the firm can expend $47 and acquire the right to produce D parts in 2 years. Furthermore, when the firm invests in license D today, it also acquires a second option associated with license E. This second option is a compound option. That is, when the firm invests in license D today, it will delay investing in license E for 2 years, at which time, the firm has the option to acquire the right to produce E parts in year 4. Downstream investment in E will only occur if it is profitable to do so and if license D is activated. To determine whether it is economically feasible to invest in license D today, management must value the options on both assets while considering the correlation between the two assets.

Table 2
Valuation input information for licenses D and E

<table>
<thead>
<tr>
<th>PMA license</th>
<th>$V_T$</th>
<th>$I$</th>
<th>$C_0$</th>
<th>$C_A$</th>
<th>FNPV</th>
<th>Decision</th>
<th>NPV</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>270</td>
<td>281</td>
<td>38</td>
<td>47</td>
<td>$-$9</td>
<td>Reject</td>
<td>$-$57</td>
<td>Reject</td>
</tr>
<tr>
<td>E</td>
<td>368</td>
<td>350</td>
<td>N/A</td>
<td>62</td>
<td>N/A</td>
<td>Reject</td>
<td>$-$18</td>
<td>Reject</td>
</tr>
</tbody>
</table>

![Fig. 4. Dual asset framework for licenses D and E.](image-url)
In order to value these options for licenses D and E correlated project values are simulated for each asset. The joint stochastic system driving the value of the two assets is

\[
\frac{dV_D}{V_D} = rdt + \sigma_D dZ_D, \\
\frac{dV_E}{V_E} = rdt + \sigma_E dZ_E,
\]

where \( \rho_{DE} = \text{Cov}(dZ_D, dZ_E) = 0.8 \). Note the two Brownian motions are correlated with each other and thus influence the movements for both assets. Once the sample paths are simulated for each asset, these values are then used to price the options. Simulated option prices for license D are found using Eq. (1) with parameter values \( D_0 = 270, r = 4\%, \sigma = 22\%, \) and \( T = 2 \) years. Simulated option prices for license E are found using Geske’s (1979) framework

\[
C_0 = e^{-rT} \left[ V_T M(k, h; \rho) - K_1 M(k - \sigma \sqrt{K_1}, h - \sigma \sqrt{K_1}; \rho) \right] - K_2 e^{-rT} N \left( k - \sigma \sqrt{T_1} \right)
\]

where \( h = \ln \left( \frac{V_T}{K_1} \right) + \frac{1}{2} \sigma^2 T_1, k = \ln \left( \frac{V_T}{K_2} \right) + \frac{1}{2} \sigma^2 T_2, V_T = \text{present value of downstream PMA part cash inflows in year 4}, \ V_C = \text{critical value above which the first call option will be exercised}, \ K_1 = \text{investment outlay for PMA part E in year 2}, \ K_2 = \text{investment outlay for the downstream PMA part E in year 4}, \ \sigma = \text{volatility of the rate of change of the downstream PMA part value}, \ r = \text{riskless rate of return}, \ N(\cdot) = \text{univariate normal distribution function}, \ M(a, b; \rho) = \text{bivariate cumulative normal distribution function}, \ \rho = (T_1/T_2)^{1/2}, \ T_1 = \text{time to maturity of the first PMA part option (within the compound option)}, \ T_2 = \text{time to maturity of the downstream PMA part option}.

Geske’s model is evaluated using the following inputs:

\( E_0 = 368, \ K_1 = 62, \ K_2 = 350, \ T_1 = 2 \) years, \( T_2 = 4 \) years, \( r = 4\%, \sigma = 22\%).

The option value for asset D is \( D_0 = 46.21 \) and the option value for asset E is \( E_0 = 65.17 \). Following the analysis in Section 3.1, management will make their decision based on the FNPV, which for this scenario is \( \text{FNPV} = (D_0 + E_0) - D_C_A \). Given that the actual option premium is \( D_C_A = 47 < D_0 + E_0 = 111.38 \), the firm is recommended to invest in license D today.

There are two points noteworthy from the above valuation. When considering the correlation between the two project values, the option value for license D increased from 38.02 to 46.21. Furthermore, if option E is calculated independent of license D the value of the compound option equals 55.59 as opposed to 65.17. It is seen that the option values increase with an increase in the correlation between the two assets due to the options’ asymmetric payoff. In other words, the greater the correlation between the two processes the greater the volatility of movements and thus the higher the chance of both options finishing in-the-money. Lastly, the key value driver for investing in license D today is management’s recognition of the downstream investment opportunity in license E. In both instances (high correlation and no correlation between the two licenses) the option value on part D is always less than the actual cost to acquire the option, which indicates investment is not recommended. Management, however, is persuaded to invest in D once they recognize a possible successful implementation of part E.
3.3. Investment cost uncertainty

The real option approaches in Sections 2 and 3 assume a known investment cost in year 2. Although a reasonable assumption for most PMA license scenarios, some of the capital expenditures in year 2 are unknown today due to input price and new technology uncertainty. Some MRO part processes require investments in special metals such as titanium and silver which cloud today’s estimates of the capital outlay in year 2. Additionally, new hardening technologies required for some parts completion are constantly being evaluated for more efficient production processes. The impact of these technologies on investment costs today is also unknown.

To account for the uncertainty in investment costs and benefits, the Margrabe (1978) model may be used:

\[ C_0 = V_0 N(d_1) - I_0 N(d_2) \]

where \( d_1 = \frac{\ln \left( \frac{V_0}{I_0} \right) + 0.5 \sigma_V^2 T}{\sigma_V \sqrt{T}} \), \( d_2 = d_1 - \sigma_I \sqrt{T} \), \( \sigma = \sqrt{\sigma_V^2 + \sigma_I^2 - 2 \rho \sigma_V \sigma_I} \), \( V_0 \) = present value of the expected cash inflows today, \( I_0 \) = expected investment outlay in today’s dollars, \( \sigma_V \) = volatility of the rate of change of the PMA cash inflows, \( \sigma_I \) = volatility of the rate of change of the investment costs, \( \rho \) = instantaneous correlation between \( V \) and \( I \), \( N(\cdot) \) = univariate normal distribution function.

Consider the information displayed in Fig. 5 and Table 3 for license F. Today’s estimated cash inflows and investment costs for part F are \( V_0 = 118 \) and \( I_0 = 121 \), respectively. Because part F

<table>
<thead>
<tr>
<th>( V_0 )</th>
<th>( I_0 )</th>
<th>( \sigma_V )</th>
<th>( \sigma_I )</th>
<th>( T )</th>
<th>( \rho )</th>
<th>( C_0 )</th>
<th>( C_A )</th>
<th>FNPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>118</td>
<td>121</td>
<td>0.22</td>
<td>0.15</td>
<td>2</td>
<td>-0.5</td>
<td>20</td>
<td>12</td>
<td>$8</td>
</tr>
</tbody>
</table>
requires investments in titanium, the cost is viewed as uncertain today. Using the historical volatility of titanium, $\sigma_I=15\%$. The correlation between $V$ and $I$ is difficult to ascertain due to insufficient data between titanium prices and an individual part’s profit. However, the firm believes that increases in titanium prices decrease $V$ due to the pricing structure of PMA parts. Thus, a baseline correlation of $\rho = -0.5$ is initially assumed. If $V$ is greater than $I$ in year 2, then investment in part F will be pursued. However, given the stochastic nature of $V$ and $I$, Eq. (3) is used to value license F and yields $C_0=20 > C_A=12$. Because FNPV>0, investment in license F is recommended today.

Fig. 6 provides a sensitivity analysis on the option’s key inputs. Consider the critical region on the plot that indicates the change in $V$ and $I$ that yield FNPV<0. If estimates for $V$ are 19% less or $I$ are 22% more than currently projected, then investing in license F would not be recommended. Additionally, note that variations in volatility and correlation have little impact on the decision. However, recall that the correlation input was crudely estimated. Table 4 performs a sensitivity analysis on the correlation. If the correlation is actually $\rho > 0.5$, then investment in license F would not be recommended. This occurs because the variance impacting the price processes actually decrease when correlation increases. In other words, an increasing correlation leads to a lower $\hat{\sigma}$ and vice versa.

### 3.4. Perpetual investment opportunity

In an effort to posture itself for future investment opportunities, the firm desires to evaluate PMA licensing opportunities on new part types with relatively little or no MRO requirements today. As aircraft age and end user requirements change, new part types offer potentially lucrative PMA licensing opportunities in the future. As expected, OEMs have first access to new MRO parts’ markets. However, being one of the first PMA suppliers of these parts could prove advantageous. Unfortunately, new PMA

<table>
<thead>
<tr>
<th>$\rho$</th>
<th>-1</th>
<th>-0.5</th>
<th>0</th>
<th>0.5</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>FNPV</td>
<td>11</td>
<td>8</td>
<td>4</td>
<td>0</td>
<td>-9</td>
</tr>
</tbody>
</table>

Table 4
Sensitivity analysis on correlation
parts’ markets are rather uncertain due to competitor entry, end-user demand, and the dynamics of the MRO industry. A PMA independent could wait years before a license yields positive cash inflows. Given the uncertainty in new MRO part types and the decision time horizon, the firm wants to value these PMA licenses within a real options context.

These licenses with uncertain and indefinite time horizon are depicted in Fig. 7. The firm’s objective is to maximize the expected present value of the following expression:

\[ F(V) = \max E[(V_T - I)e^{-rT}] \]

where \( V_T \) = present value of cash inflows, \( I \) = investment cost, and \( T \) = unknown passage time of \( V_T \). In other words, given the time value of money, investment cost, and project value at unknown time \( T' \), determine the value of \( V_T, V^* \), that maximizes the expected payoff. Unfortunately, time \( T' \) may not be determined today because of the stochastic nature of \( V_T \). However, expression (4) does have solution assuming \( V_T \) follows geometric Brownian motion. The value of the license today under this perpetual call option (e.g., Dixit & Pindyck, 1994; Samuelson, 1965) framework is:

\[
C_0 = \begin{cases} 
\left( \frac{I}{c - 1} \right) \frac{V_0(c - 1)}{cI} & \text{when } V_0 \leq V^* \\
(V_0 - I) & \text{when } V_0 \geq V^* 
\end{cases}
\]

where \( c = \sqrt{(r-q-0.5\sigma^2)^2 + 2r\sigma^2} - (r-q-0.5\sigma^2) \), \( V^* = cI/(C-1) \), \( V_0 \) = present value of the cash inflows today, \( I \) = investment outlay, \( r \) = riskless rate of interest, \( q \) = dividend yield or the rate-of-return shortfall, \( \sigma \) = volatility of the rate of change of the cash inflows.

Table 5
Valuation information for license G

<table>
<thead>
<tr>
<th>( V_0 )</th>
<th>( I )</th>
<th>( r )</th>
<th>( q )</th>
<th>( \sigma )</th>
<th>( c )</th>
<th>( V^* )</th>
<th>( C_0 )</th>
<th>( C_\Lambda )</th>
<th>FNPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>348</td>
<td>388</td>
<td>0.04</td>
<td>0.05</td>
<td>0.22</td>
<td>2.17</td>
<td>719</td>
<td>68</td>
<td>52</td>
<td>$16</td>
</tr>
</tbody>
</table>
Consider the information in Table 5 for license G. The rate-of-return shortfall, \( q \), represents the opportunity cost of delaying the investment decision.\(^6\) For this license scenario, it represents the costs associated with competitors acquiring initial market share of part G. In general, estimating a reasonable rate-of-return shortfall is difficult in practice. If \( V_T \) may be linked to a publicly traded future’s price, then an estimate of \( q \) is the convenience yield. In this sense, the value of the option is discounted because the firm loses the ability of taking advantage of opportunities in the market today. For our analysis, a baseline \( q \) is set equal to 5\%. Using Eq. (5), license G is worth \( C_0=68 > C_A=52 \) and investment is recommended.

Fig. 8 provides a sensitivity analysis on the perpetual option’s key inputs. Notice that variations in each input reverse the license acceptance decision—\( q \) increasing by 25\%, \( I \) increasing by 20\%, \( V_T \) decreasing by 10\%, and \( \sigma \) decreasing by 20\%. In agreement with management’s intuition, this high sensitivity points to the strategic nature of pursuing licenses on new MRO part items. And the sensitivity analysis provides a technique for the firm to determine its ‘comfort zone’ when identifying and pursuing these licenses. Thus, a benefit of the real options approach is the structured decision guidelines concerning investment opportunities with uncertain project benefits and decision time horizon, investment costs, competitor influences, and uncertainty. This ability to quantify project acceptance ranges is an important contribution to informed decision-making.

4. Key insights and concluding remarks

Several real options frameworks were demonstrated to value PMA licenses within the MRO industry. Given the market size, competition, and air travel demand uncertainty, the real options framework provides a structured methodology to recognize key valuation inputs. The PMA licensing scenarios above were developed with Fairchild personnel to explore the feasibility of the real options approach to value its licensing opportunities. Although the application of these off-the-shelf option calculators does imply a certain degree of oversimplification, the process of categorizing the licenses into four options frameworks

\(^6\) To cope with this problem, Constantinides (1978), McDonald and Siegel (1986), and Trigeorgis (1996) define the difference between growth rates on traded and non-traded assets as the rate of return short fall. To incorporate this short fall into our analysis, we decrease the project’s discounted value at year 2 by the present value of the first year revenue. The shortfall represents the opportunity cost of not getting to the market as quick as possible. If the firm really pushed the FAA license along, then it could get to the market in year 1 instead of year 2. Therefore, the shortfall represents the possible lost cash flows from the extra 1 year delay.
proved rewarding and insightful. In fact, the personnel we interacted with believed the real options framework provides a viable technique to gauge license value and guide decision-making.

Further, Fairchild staff approximated the types of licenses and corresponding real options technique for its PMA parts candidates. Table 6 contains this aggregation. The firm believes 20% of its PMA licenses may be valued with discounted cash flow techniques. These licenses have low uncertainty due to their similar attributes with existing product lines. However, notice that 80% of PMA candidates fit within the real options model. Thirty percent of the licensing opportunities may be framed within a traditional licensing scenario and valued with the European futures option framework. These 20% represent the target group for the immediate future real options valuations. Given the ease of implementing the futures option model, the firm believes it can use the approach to identify feasible candidates for further study. More importantly, however, by maximizing FNPV the firm will be able to identify PMA licenses not worth pursuing. In other words, sometimes ascertaining ‘what not to pursue’ is just as important as ‘what to pursue’. Another 30% of the licensing candidates are dependent upon one another and may be framed as compound options. Although requiring more input estimates, the firm believes it can use the compound options approach to justify several of its growth (or platform) PMA licensing strategies. The firm believes investment cost uncertainty impacts 10% of the proposed PMA licenses and plans on implementing the Margrabe exchange option. Finally, when considering the riskier new MRO parts market, the firm wants to experiment with the perpetual options framework and its numerous variants (Dixit & Pindyck, 1994).

In short, the process of introducing options theory to value PMA licenses provides some important insights for decision-makers. For instance, when Fairchild’s managers have the ability to postpone investment, face a high degree of uncertainty over future events and some if not all of the initial investment is not recoverable or completely irreversible the use of real options analysis helps the firm recognize value that is overlooked by traditional discounted cash flow methods. This leads managers to allocate the firms resources to their most productive use. Furthermore, Fairchild finds that appropriately categorizing its strategic decisions allows managers to apply more suitable valuation methods to make efficient decisions. In general, managers wish to make the most informed decisions as to direct the firm’s capital to its most efficient use. Real options analysis is a tool that provides a medium for managers who must make strategic decisions in a dynamic setting.

References
